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AREA OFFICERS
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DIGEST

This report contains a description and analysis of tests made on a New York, Chicago & St. Louis Railroad bridge located at Fillmore, Ill. The bridge consists of five 28-ft open-deck beam spans supported on pile piers constructed of Armco spiral welded pipe piles filled with concrete. The tests were made with a special test train operating over a complete range of speeds from 5 mph up to a maximum of 58 mph. The purpose of the tests was to determine the static and dynamic effects of a steam locomotive operating over the bridge at a full range of speeds under the following conditions: (1) All timber bracing on the piers in place; (2) all timber bracing removed from the piers; and (3) new steel bracing on pier 3.

The stresses were measured in various parts of the bridge under 234 eastbound test runs by means of wire resistance strain gages with oscillograph recordings. Data on the following were obtained:

Bottom flanges at the center of beam spans.

Top flange at the center of a beam span.

Concrete filled pipe piles near the ground line on:

(1) A short pier with no bracing,
(2) High piers with timber bracing in place,
(3) High piers with timber bracing removed,
(4) A high pier with new steel bracing in place.

Concrete filled pipe piles near the cap, at mid-height and near the ground line on:

(1) A high pier with timber bracing removed,
(2) A high pier with new steel bracing in place.

Timber bracing.

Webs of running rails at the abutments.

The data secured during these tests were analyzed for the particular purpose of segregating and determining the magnitude of the static stresses, maximum stresses, total impact effects, load distribution to the piles, lateral and longitudinal bending, and equivalent static lateral and longitudinal forces due to normal operation and due to braking. A brief summary of the analysis of the data, as found from this study, is as follows:

1. The recorded static stresses in the bottom flanges of spans 1, 2, and 3 were about 79 percent of the calculated stress of 7.08 ksi, which was based upon concentrated wheel loads and the gross moment of inertia of the section. A comparison of the recorded and calculated stresses and the stress factors in the lower flanges is shown in Table 1 (page 43).

2. The recorded static stresses on the inside of the top flange near the center of span 2 were about 3 times greater than the stress on the outside of the top flange, as can be seen from the upper left diagram of Fig. 9. It was observed that the tie directly over the gages was bearing near the outer edge of the flange, thereby introducing local bending.

3. The roll effects (at rail centers) in percent of the recorded static stress shown in the diagrams of Fig. 10 were less than the AREA design requirement of 20 percent.

4. The combined track and hammer-blow effects recorded under passage of the steam locomotive are shown in Fig. 11. This direct vertical effect caused by wheel and track irregularities and the periodic disturbing force of the counterweights amounted to about 30 percent of the recorded static live-load stresses and exceeded the calculated hammer-blow stresses, as shown by the solid and dashed curves.

5. The maximum live load plus impact stresses in the lower flanges of spans 1, 2 and 3 are shown in the diagrams on Fig. 12. The recorded maximum stresses were considerably less than the calculated maximum stresses, and in general there was an increase in maximum stresses with an increase in speed.

6. The total impact effects, which are a combination of speed effect, roll effect and track and hammer-blow effects, are shown in Fig. 13 for spans 1, 2 and 3. The total impacts in all 3 spans were considerably less than the AREA design requirement of about 74 percent. The impacts in span 1 were as high as 55 percent, apparently due to the fact that one end of the span rests on a solid concrete abutment. The relatively low values of impact in spans 2 and 3 may be attributed to the resilience of the pile piers.

7. A comparison of the recorded and calculated direct live-load static stresses and the stress factors for the piles near the ground line in piers 2, 3 and 4 are shown for 5 static runs in Table 2 (page 43). The recorded static stresses varied from 5.6 percent greater to 11.2 percent less than the calculated static stress of 1.63 ksi, with the average of all 6 piles slightly less than the calculated.

8. The maximum recorded pile loads, determined from the pile stress and a load factor found in the laboratory, are shown in the upper diagrams of Figs. 14 and 15 for piers 2, 3 and 4 under the 3 conditions of loading: timber bracing in place, timber bracing removed, and steel bracing in place. These figures clearly indicate that the maximum recorded pile loads for all piles tested were generally between 40 and 50 kips and that the bracing had no effect on the magnitude of the pile loads, as would be expected.

9. The total impacts on the piles expressed as a percentage of the recorded static load are shown in the lower diagrams of Figs. 14 and 15. The greatest impact recorded amounted to 26.5 percent in the piles of pier 4 with timber bracing removed. It can be seen that appreciable impact does exist in the piles of this structure.

10. The distribution of the live load to the individual piles in each pier for a full range of speeds is shown in Figs. 16 and 17. The average calculated static load per pile was 43.4 kips. The loads are expressed as a percentage of the sum of the total load on each pier, and a perfect distribution would require a pile to carry 16.7 percent of the total load on the pier. It can be seen from the curves at the bottom of Figs. 16 and 17 that the distribution varied from about 13 to 20 percent, and that the battered piles carried a full share of the load.

11. The tests conducted with gages on the piles near the ground line indicated that the piles were subjected to lateral and longitudinal bending, which is taken as the difference between the largest stress and the average stress in the lateral and longitudinal directions. This bending, expressed as a percentage of the axial stress, is shown in Figs. 18 and 19 for the lateral bending and in Figs. 20, 21 and 22 for the longitudinal bending. However, it must be pointed out that, although the lateral bending stress was as high as 108 percent of the axial stress in one instance (see Fig. 19, pier 4, pile 6), on the average the bending is only 37 percent for the worst condition (timber bracing removed, Fig. 18, pier 3, pile 2). The timber bracing and steel bracing reduced the lateral bending compared with the unbraced condition. The longitudinal bending was

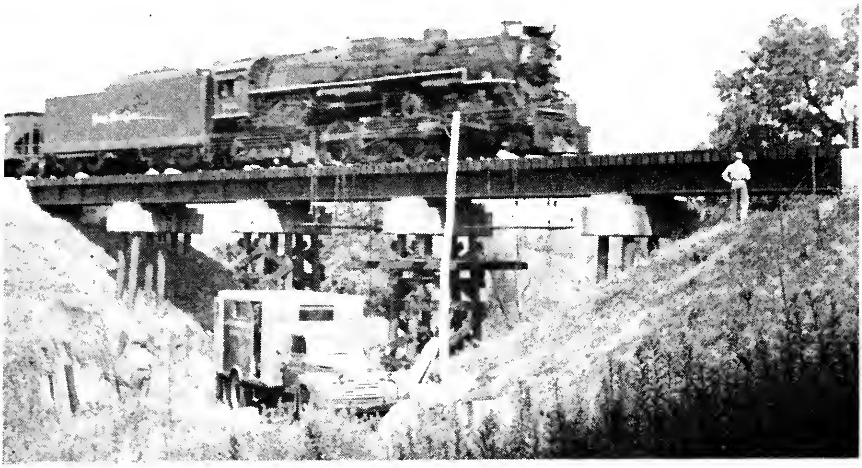


Fig. 1 (above)—General view of bridge and test train at Fillmore, Ill. Fig. 2 (below)—View of pier 3, showing type of timber bracing used.

Fig. 3 (above)—View of pier 4, showing piles with timber bracing removed. Fig. 4 (right)—View of pier 3, showing new steel bracing welded to piles at 11 ft 1 in from bottom of concrete cap.

considerably less than the lateral bending and was not reduced by the use of either steel or timber bracing.

12. The tests conducted with gages located at 3 positions on 2 piles in pier 3 afforded an opportunity to determine the point of contraflexure and point of fixity of the piles. However, this analysis was hampered by the fact that only 3 gage locations were used for measurement. Therefore, the type of analysis shown in Fig. 23 will yield only the order of magnitude of equivalent static longitudinal and lateral bending forces on the pier. However, using the analysis set forth in Fig. 23, and assuming the point of contraflexure remains constant regardless of bracing, the equivalent static lateral forces acting on piers 3 and 4 were calculated and are shown in Fig. 24. The maximum equivalent static lateral force computed was 4.50 kips compared to the AREA design of 20 kips.

13. Tests were made with gages located on the piles near the cap, near the ground line and on the running rails simultaneously to determine the forces produced by the test train braking to a stop. Typical traces reproduced on Fig. 7 illustrate the effect of braking to a stop on the bridge. For train position "A" on Fig. 7 the longitudinal force at the instant of stopping was 62.8 kips tension at abutment 6, and 19.8 kips compression at abutment 1, or a total force in the rails of 82.6 kips for this particular run.

14. The longitudinal forces produced by the locomotive under normal operation, as well as service braking and braking to a stop, are shown on Fig. 25 for piers 3 and 4. The maximum longitudinal force taken by one pier was 2.25 kips, considerably lower than the AREA design force of 39 kips (15 percent of the pier reaction), and it can be seen that the forces on pier 3 due to braking to a stop were not much higher than for normal operation. The longitudinal forces in the rails determined simultaneously varied from 54.6 to 127.5 kips, indicating that the rails were carrying the greater part of the total longitudinal force produced by the test train braking to a stop on the structure.

16. The maximum stresses, tensile or compressive, recorded in the timber bracing on pier 3 are shown in Fig. 26. The maximum stresses varied from 105 psi tension to 112 psi compression, which is equivalent to a direct load of 3780 or 4030 lb, respectively, in the 3-in by 12-in bracing. The bracing undoubtedly stiffened the long unsupported piles, appreciably reducing the amount of vibration present.

FOREWORD

Bridge 388.83 at Fillmore, Ill., on the Cloverleaf District of the New York, Chicago & St. Louis Railroad, afforded an excellent opportunity to measure the stresses in a new structure of this type. Completed in December 1950, this bridge, which consists of five 28-ft open-deck beam spans supported on Armco spiral welded pipe filled with concrete, replaced an 11-span timber trestle. Originally, the NYC&StL had authorized the replacement of the timber trestle with one 33-ft steel span on concrete abutments, but it later developed that it could construct a bridge with shorter beam spans supported by concrete-filled steel piles at a saving of about $30,000, or half of the total estimated cost of the original design. The actual gross cost of the new bridge averaged $250 per lin ft.

Shortly after the new bridge was opened to regular traffic, the railroad engineers noticed that there was considerable lateral movement at the caps of piers which had an unsupported height of over 20 ft. This lateral movement was estimated to be about 0.10 in. To remedy this they installed 3-in by 12-in timber bracing on the two high piers. In order to check the effectiveness of this timber bracing and also to check other design features, such as the load and impact on the piles, the NYC&StL felt that it would be advantageous to have tests made. An initial experimental stress analysis of the pipe pile piers using SR-4 strain gages both dynamically and statically was made on this bridge by the Research Division of the Armco Steel Corporation with the cooperation of the

NYC&StL. The data developed proved sufficiently interesting to prompt a more extensive investigation of the entire structure.

AREA Committee 30—Impact and Bridge Stresses, became interested in this type of bridge and decided that a study of this structure would be valuable for obtaining data for its Assignment 6—Determination of Braking and Traction Forces in Bridge Structures, Collaborating with Committees 7, 8 and 15. The committee requested the research staff of the Association of American Railroads to conduct tests to determine braking and traction forces as well as other dynamic effects, such as impact and bending stresses on the beams and piles, and lateral and longitudinal forces on the piers.

The tests were started on July 28, 1952, and completed by August 8, 1952. Two hundred and thirty-four runs were recorded under the passage of a test train and under the following conditions: (1) All timber bracing in place, (2) all timber bracing removed, and (3) new steel bracing on pier 3. The preceding three conditions are illustrated in Figs. 2, 3 and 4.

The tests covered in this report were conducted for AREA Committee 30—Impact and Bridge Stresses, and were carried out under the general direction of G. M. Magee, director of engineering research, Engineering Division, AAR. The funds necessary for the tests were provided by the AAR.

The conduct of the tests, analysis of data, and preparation of the report were under the direction of E. J. Ruble, research engineer structures, Engineering Division, research staff, AAR, assisted in the office work by A. A. Sirel, assistant research engineer structures, and in the field testing work by M. F. Smucker, assistant electrical engineer. This report was prepared by W. C. Panarese, draftsman.

TEST SPAN AND LOCATION OF GAGES

This structure, which is located on tangent track with level grade, consists of five 28-ft open-deck single-track beam spans supported on 4 pile bent piers and 2 abutments, as shown in Figs. 1 and 5. Each span has one 33 WF 240-lb beam per rail resting on concrete caps. The bridge was designed in accordance with the 1950 AREA specifications, using Cooper E 72 loading. The live-load impact allowance for the beam spans was 73.8 percent. The design load for the piles for dead load and E 72 live load plus 25 percent impact was 71,000 lb per pile.

The piers consist of 6 concrete-filled Armco spiral welded pipe piles, which are 12¾ in. in outside diameter and have a ¼-in wall thickness. The 4 corner piles in each pier were driven with a batter of 1 to 12. The 6 piles in each pier are capped with a poured-in-place reinforced concrete cap, 5 ft 6 in wide, 4 ft deep, and 12 ft 6 in long. Each pile extends into the cap a distance of 1 ft. The pile spacing at the cap is 4 ft 3 in, while the spacing between bents in each pier is 3 ft. Creosoted timber bracing, 3 in by 12 in, was used on piers 3 and 4, in which the unsupported pile length exceeded 20 ft. Special U-bolts were used to fasten the bracing to the piles, as shown for pier 3 in Fig. 2.

SR-4 gages were applied to various elements of the structure, as shown in Fig. 5, to determine the tensile and compressive stresses in the flanges of the WF beams, the compressive axial and bending stresses in the concrete-filled piles just above the ground line, and the axial stresses in the timber bracing. In addition to the gages shown in Fig. 5, ½-in SR-4 gages were located longitudinally on the web of the rails, as shown in Fig. 7, to establish the stresses in the rails caused by braking and traction. Gages were also mounted at the top and mid-height of the southeast and center east pile of pier 3, as shown in Fig. 25, in order to study the bending moment and point of contraflexure of the piles with the timber bracing removed.

TEST TRAIN

The test train used in these tests consisted of a NYC&StL steam locomotive (class S) followed by four heavily loaded cars and a caboose. The required general data necessary for computing the static live-load stresses are shown in the top diagram of Fig. 6. The rating of this locomotive, in terms of Cooper loading for moment at the center of a 27-ft 10-in beam span, was E 56.2.

The components and resultant unbalanced weights causing dynamic augment are shown for the test locomotive in Fig. 6. This locomotive has an average reciprocating unbalance per side per 1000 lb of locomotive weight in working order of 3.79 lb, and an average reciprocating compensation of 35 percent. All the drivers of this locomotive are straight balanced, with the exception of the main drivers which are cross counter balanced.

The necessary information regarding this test locomotive, such as axle weights, axle spacing, nominal wheel diameters, and all information required to calculate the components and resultant unbalanced weights on the driving wheels, was furnished by the mechanical department of the NYC&StL.

INSTRUMENTS

The electrical type instruments used in these tests to determine the stresses in the beams, piles and bracing consisted principally of two 12-element oscillographs which recorded the stresses by means of SR–4 wire resistance gages. A detailed description of oscillographs and their auxiliary units is given in the AREA Proceedings, Vol. 46, 1945, page 201, and a description of SR–4 wire resistance gages, with the necessary recording equipment, is given in the AREA Proceedings, Vol. 52, 1951, page 152.

The SR–4 wire resistance gages in all cases had a gage length of ½ in, with the exception of those on the timber bracing, which had a 6-in gage length. The rail gages consisted of two ½-in SR–4 gages applied longitudinally on both sides of the web near the neutral axis. The gages were placed in series in the electrical circuit, resulting in the recording of an average stress across the web of the rail.

A close check was maintained on the sensitivity of each gage in the field so that the relation between the strain in the steel and the amount of deflection of the oscillogram trace can be considered accurate to within a small percentage. For these tests a sensitivity of 1 in equal to 0.000333 in per in was used for gages located on the steel beams. This means that a 1-in deflection of the light trace on the oscillogram represents a unit strain of 0.000333 in per in at that particular gage location. This would be equivalent to a stress of 10,000 psi in the steel, assuming a modulus of elastically of 30,000,000 psi for the steel in the beams. For gages located on the piles, a sensitivity of 1 in equal to 0.000083 in per in was used, or a 1 in deflection of the light trace corresponded to a strain of 0.000083 in per in on the steel in the piles. This unit strain was equal to a stress of 2500 psi, assuming a modulus of elasticity of 30,000,000 psi for steel in the piles. A sensitivity of 1 in equal to 0.000083 in per in was also used for gages located on the timber bracing. This would correspond to a unit strain of 0.000083 in per in. in the timber and a stress of 182 psi based upon a modulus of elasticity of 2,180,000 psi for this particular timber for strain parallel to the grain. The modulus of elasticity of the timber was computed from the specific gravity of several samples of wood taken from the core and surface of the timber bracing. The method of computation is described in "The Wood Handbook" (Table 10, page 60) published by the Forest Products Laboratory.

The pile loads in these tests were determined by using a load factor established by experimental load test data at the University of Illinois in 1947 on 12¾-in by ¼-in

Armco spiral welded pipe ("Tests on Concrete Filled Spiral Welded Pipe" by W. E. Black and R. L. Brown). In these University of Illinois tests full-size concrete-filled piles were loaded in compression, and it was found that a load of 800 lb on a pile resulted in a strain of 1 micro-in (0.000001 in) on the outside surface of the steel. Therefore, a stress of 1 psi on the outside surface of the steel was considered equivalent to an axial load of 26.67 lb on the pile. This load factor was checked against a factor determined theoretically by using the transformed area method, and the two values were in excellent agreement. The ratio of the modulus of elasticity of the steel to the modulus of elasticity of the concrete was assumed to be 7.

ANALYSIS OF FIELD RECORDS

The test records consisted of 468 oscillograms from the 234 test runs, which were photographed on sensitized paper 10 in wide. The oscillograms vary from 1 to 5 ft in length, depending on the speed of the oscillograph, which in turn is regulated with the speed of each particular run. For example, at less than 10 mph a film speed of 1 in per sec was used, whereas at a speed of 50 mph or more, a film speed of 4 in per sec was used. The oscillograph and run number automatically photographed on the record after the completion of each run refers to a log of test runs which shows the direction, approximate speed, time of run, and all other necessary data regarding the test runs and recording equipment. Since the inclusion of all 468 oscillograms would be impractical and too voluminous for this report, only typical oscillograms are reproduced, as shown in Figs. 7 and 8. The remaining oscillograms are on file at the AAR Research Center, Chicago.

For an analysis of the oscillograms it was first necessary to determine the base line, or line of zero stress for each of the 12 traces on each record. The first 2 or 3 in of the record were taken before the locomotive reached the bridge; the record was again started when the locomotive was about 2 spans away from the test span or pier and continued until the locomotive and tender were off the test span or pier. The final 2 or 3 in of record were not taken until the entire train had passed over the bridge. Base lines representing zero stress were then drawn from one side of the light trace for all 12 gages connecting the 2 "no-load" parts of the oscillogram. It was next necessary to locate the time of maximum simultaneous deviation of the light trace for all gages located at a common section on the part of the structure under study. For example, in Fig. 8 the line labeled "position of train for maximum lateral bending in east piles, gages A2, A4, A6, A8, A10, and A12" represents the time when the lateral forces produced a maximum deflection of the light trace from the base line. The drivers of the locomotive at the time of maximum deflection of the light traces from the base line were located as shown in the "Elevation" on the figure. It can be seen from this oscillogram that the east piles were oscillating laterally, as indicated by the gages on the north side of the piles deflecting in opposite direction to those on the south side. This opposite action of the light traces means that the stress on one side of the piles, say gage positions A2, A6 and A10, was decreasing in compression, while the stress on the opposite side, gage positions A4, A8 and A12, was increasing in compression, due to the lateral bending. To determine the magnitude of these lateral stresses in the piles and to distinguish these stresses from the axial compressive stresses caused by the wheel loads on the span, lines were drawn on the oscillograms indicating the upper and lower envelope curves through the peaks and valleys of the oscillations, as is shown on the typical oscillogram. One-half of this oscillation, or the semi-amplitude of vibration, is then the bending stress on that particular side of the pile resulting from the lateral force, while the distance from the base line to the mean stress curve, drawn only for gage position A4 on the typical oscillogram, is the axial load. The average semi-amplitude recorded on the two sides of each pile was taken as the stress in the pile resulting from the lateral force.

The above method of analysis is applicable for determining stresses due to lateral force caused by the nosing of the locomotive, and a similar type of analysis was also used to read other dynamic effects from the oscillographs, except that the envelopes of the traces were not drawn and semi-amplitudes were not measured. For example, to find the stresses in the piles due to longitudinal bending at the bottom of pier 4 (see Section 6–6 in Fig. 5) it was first necessary to draw the base lines for all 24 gages. The line of maximum deviation of the traces from the base lines was then found for all 24 gages simultaneously. Finally, the deviation of each trace was measured in hundredths of an inch and multiplied by the stress factor, or sensitivity, to establish the stress at each gage location. The method used to find the actual longitudinal bending stresses from the four stress readings on each pile will be taken up in the latter part of this report.

Irregularities in the traces or the amplitudes of stress are caused by vibrations in the span induced by uneven track, out-of-round wheels, and the effect of locomotive hammer blow. At slow speeds, such as 5 to 10 mph, the traces are very regular, indicating little or no effect due to track and hammer blow, so the oscillograms secured at these speeds were used for determining static stresses.

The typical traces shown in Fig. 7 indicate the type of stress induced in the rails at each end of the bridge and in the piles of pier 3 as a result of the train braking to a stop. The analysis of this type of oscillogram will be taken up in the latter part of this report.

STATIC, DYNAMIC AND OTHER EFFECTS

The data as read from the oscillograms were tabulated and analyzed for the particular purpose of segregating and determining the magnitude of the various static and dynamic effects of the live load. The results of this study are as follows:

Beam Spans

Static Stresses

Static stresses were measured in the lower flanges of spans 1, 2 and 3, and in the upper flange of span 2, as shown in the location of gages on Fig. 5. The recorded static stresses were determined from the maximum mean stresses secured under slow-speed runs of approximately 5 mph. The static stress in the lower flanges of spans 1 and 3 was the greatest mean stress recorded by the one gage located at the center of each beam. The two traces for the spans were read simultaneously. The static stress on the lower side of the upper flange in span 2 was also the greatest mean stress which was recorded and read simultaneously with the 3 gages on each of the bottom flanges of this span, while the static stress in the bottom flange was the mean stress recorded by the middle gage. The exact position of the locomotive wheels at time of maximum recorded stress was secured from the wheel position marks on the oscillograms, and the same locomotive position was used for the calculated stress. In most cases this position of the wheels for maximum recorded stress met the criteria for calculated maximum stress at the gage position. Concentrated wheel loads were used to compute the bending moment, and the stresses are based upon the gross moment of inertia of the section.

A comparison of the recorded and calculated live-load static stresses and the stress factors, or ratios of the recorded to calculated stresses, in the lower flanges of the beams at the center of spans 1, 2 and 3 are shown for 5 static runs in Table 1. The static stresses recorded in each beam and the average of the two beams are shown in Cols. 4, 5 and 6 of this table, while the calculated live-load stress is shown in Col. 7. The static stresses, recorded under eastbound trains only, are, on the average, 79 percent of the calculated stress. This is in line with what has been found in previous tests where static live-load stresses were measured at the center of short spans. The principal reason for the difference between the recorded and calculated stresses is believed to be caused by a redistribution of the locomotive axle loads. As the span deflects under live load, the center axles, which effect bending moment the most, become lower than the end axles; consequently, part of the load on these axles may be transferred forward and backward to the end axles by the equalizing system. Experience with locomotive scales has indicated a redistribution of axle loads when the axles change elevation relative to each other. It should also be kept in mind that the calculated stress was computed by using concentrated axle loads. It has been found in previous tests that the rail acts as a continuous beam on an elastic support, and the continuous action of the rail would result in a longitudinal distribution of the wheel loads and a lower calculated stress by 10 to 15 percent.

Static stresses were measured in the top flange near the center of span 2 for one beam only, as shown in the "Elevation" on Fig. 9. The compressive static stresses measured on the inside of the top flange were about three times greater than those measured on the outside of the top flange, as can be seen for the illustration in the upper left diagram of Fig. 9. For this particular run at 4.5 mph, the compressive stress on the inside upper flange was 6.60 ksi as compared with only 2.10 ksi on the outside. This unusual distribution of stress was found to hold true for all runs and not only those applicable for determining static stresses, as can be seen from the diagram in the upper right corner of Fig. 9 for an eastbound run at 57.5 mph. This unusual stress distribution was noted in the field after a few of the oscillograms were developed, and while searching for an explanation it was observed that the tie located immediately over the gages on the top flange (see "Elevation", Fig. 9) was bearing only on the outer edge while as much as ¼ in of space could be seen between the inner edge of the flange and the tie. This eccentric bearing of the tie on the beam caused local bending which induced a tensile strain in the lower edge of the outer top flange, thereby reducing the compressive stress considerably at that particular gage location.

The variation of static stresses across the bottom flange at the center of span 2 is also illustrated by the diagram in the upper left corner of Fig. 9. It can be seen that the tensile stress varied from 5.40 to 5.80 ksi in the south beam and from 5.50 to 6.40 ksi in the north beam for this particular run at 4.5 mph. About the same percentage of variation was found for all the locomotive speeds.

Roll Effect

An increased mean stress in one beam with a corresponding decrease in the mean stress in the other beam of the same span is undoubtedly due to the spring-borne weight of the locomotive oscillating about a longitudinal axis. This oscillation is probably set up not only by track inequalities, but also by the locomotive weaving or nosing from side to side. This increase in the mean stress in one beam is called roll effect. The magnitude of the increase in stress in one beam was found by subtracting the average simultaneous mean stress of both beams from the maximum mean stress recorded during the same run. The increase in pressure on the rail which would produce the recorded difference in stress, in percentage of the recorded static stress, is shown on Fig. 10 for 19 eastbound runs over the 3 test spans at speeds varying from 8.9 to 57.5 mph. For example, when the test locomotive passed over span 1 at 4.2 rps, or 51.6 mph (see Fig. 10), the mean stress in the south beam was found to be 13.9 percent greater than the average stress in both beams, due to an increase in pressure on the south rail of 18.0 percent, as shown by the solid circle for this particular run. The solid symbols represent a roll towards the south, while the open symbols represent a roll towards the north. It can be seen that the direction of roll on span 1 was predominantly towards the south, while in spans 2 and 3 the roll was towards the north. This would tend to indicate that there was some track condition tending to roll the locomotive south on span 1 and north on spans 2 and 3. There is considerable variation in the roll effect found in the three spans, and it does not appear to bear any relation to locomotive speed. In only a few cases did the roli effect exceed 10 percent, and in no case did it exceed the present AREA design requirement of 20 percent.

Track and Hammer-Blow Effect

The vertical vibrations produced in a railroad bridge by the passage of a steam locomotive are undoubtedly caused by a combination of wheel and track irregularities and the periodic disturbing force of the counterweights. This disturbing force, or hammer blow, of the steam locomotive is due to the centrifugal force of the unbalanced weights on the revolving driving wheels. It is quite possible that in some cases the condition of the track would tend to counteract the vibrations due to hammer blow, and in other cases the vibrations due to track conditions might be additive to the vibrations caused by the hammer blow. Since there is no way to determine the separate effects for these tests, the only alternative is to report their combined effect.

The combined track and hammer-blow stresses, or stress semi-amplitudes of vibration, as read from the oscillograms for the three test spans, are plotted on the upper diagrams of Fig. 11 for 22 eastbound runs varying in speed from 3.4 to 57.5 mph. The maximum calculated stresses in the beam flanges caused by the resultant weights producing dynamic augment or hammer blow of the locomotive drivers, without magnification, are shown by the solid and dashed curve lines of these figures. For example, the calculated maximum stress in the lower flange at the center of the north beam in span 3, produced by the vertical components of the resultant unbalanced weights in the drivers of the test locomotive (see Fig. 6), with the left crank pins at 31 deg with the vertical, is 0.054 ksi when the locomotive is operating at 1 rps, and 1.26 ksi when operating at 5 rps. The maximum calculated stress possible in the south beam of the same span with the test locomotive operating in the same direction, but with the right crank pins at 32 deg with the vertical, is 0.040 ksi at a speed of 1 rps, and 1.015 ksi at a speed of 5 rps (see curves of maximum hammer-blow static stress on Fig. 11). The static hammer-blow stress curves are the maximum determined for each beam separately and are based upon the gross steel section. The values which determine the curves shown on Fig. 11 have been corrected by the proper stress factor based upon the ratio of the recorded to the calculated static stresses taken from Table 1 for each beam in the three spans.

The track and hammer-blow effects, expressed as a percentage of the recorded static stresses, are shown in the lower diagrams of Fig. 11. In general, the track and hammer-blow effects amounted to about 30 percent of the recorded static live-load stresses and exceeded those calculated by a considerable amount.

Maximum Stresses

The maximum live-load plus impact stresses recorded in the lower flanges of the beams at the center of spans 1, 2 and 3 under passage of the test train are shown in

Fig. 12 for a full range of speeds. The maximum stresses shown are the maximum values read from the oscillogram for one gage while reading the north and south beams simultaneously. Also included in Fig. 12 are the calculated static and calculated maximum stresses, based on the AREA design specifications, and the recorded static stress for each beam. It can be seen that the recorded maximum stresses are well below the calculated maximum stresses, as would be expected for the same reasons that the recorded static stresses were appreciably lower than the calculated static stresses. In general, there appears to be an increase in maximum stresses with an increase in speed; however, it can be seen that at high speeds it is not unusual to record stresses which are as low as or lower than those recorded at very low speeds. This may be due to a rolling of the locomotive about a longitudinal axis, which would increase the load on one beam with a corresponding decrease in the load on the other beam, or a vertical acceleration of the sprung weight of the locomotive, which would cause a decrease in load on both beams. It is evident from Fig. 12 that the maximum stresses are greater in the south beam of span 1 and the north beam of spans 2 and 3. This is in good agreement with the direction of roll indicated in Fig. 10 for each test span.

Total Impacts

The total impacts recorded in the lower flanges of the beams at the center of spans 1, 2 and 3 under passage of the test train for a full range of speeds are shown in the diagrams of Fig. 13. The total impact percentage in each test run for a particular speed is the increase in the stress in the beam over that occurring at a slow-speed run, approximately 5 mph, for the same locomotive. The total impacts are the combination of speed effect, roll effect, and track and hammer-blow effects, and it would be unlikely that the maximum for all effects would occur simultaneously. This can be seen from the diagrams of total impacts on Fig. 13 where considerable scattering of the impact values, even at the same speeds, indicates that not all of the impact effects are a maximum at the same time. These diagrams show the impact percentage as computed by the AREA design specification for rolling equipment with hammer blow, and it can be seen that the recorded values are considerably below the specified values. The diagrams also indicate that there is an increase in total impacts with an increase in locomotive speed. It should be kept in mind that the recorded static stresses in these spans were about 21 percent below those calculated; thus, any impact stress shows a larger percentage of the recorded static stress. It should also be kept in mind that the rigidity of the foundation upon which a steel span rests is an important factor affecting impact. For example, a steel span supported on massive concrete piers or abutments would have higher total impact readings than a similar span supported on slender pile piers, such as those in this particular bridge. These piers undoubtedly impart resilience to the structure, which may account for the low recorded total impacts. The fact that one end of span 1 rests on a solid concrete abutment while the other end rests on a relatively short and rigid pile pier, appears to be the reason why the total impacts recorded in this span exceeded those recorded in spans 2 and 3.

Pile Piers

Static Stresses

Direct static stresses were recorded in the piles of piers 2, 3 and 4 near the ground line, as shown in "Sections 4–4, 5–5 and 6–6" of Fig. 5. The recorded static stresses were determined from the maximum mean stress secured under slow-speed runs of approximately 5 mph. The maximum mean stresses were read simultaneously from the oscillograms for all the gages located on the six piles of each pier. The exact position of the locomotive wheels at time of maximum recorded stress was secured from the wheel position marker on the oscillograms, and the same locomotive position was used for the calculated stress. In most cases this position of the wheels for maximum recorded stress was in good agreement with the position of wheels determined by using the criteria for calculated maximum pier loads. The calculated average static stress in the six piles of each pier was computed for maximum live-load reaction on the piers. The direct static stress was determined from the average load on the pile, employing the method of transformed section to find the stress. The ratio of the modulus of elasticity of steel to that of concrete was assumed to be 7. The calculated static stress was also computed by using the load factor (26.67 lb axial load equals 1 psi on the outer fibers of the steel pile) discussed previously, and excellent agreement was found between the two methods.

A comparison of the recorded and calculated direct live-load static stresses and the stress factors, or ratios of the recorded to calculated stresses, for the piles in piers 2, 3 and 4 are shown for 5 slow-speed runs in Table 2. The recorded stresses shown in Cols. 5, 8, 11, 14, 17 and 20 are the average of 2 gages on each of the 6 piles in pier 2 and the average of 4 gages on each of the 6 piles in piers 3 and 4. The calculated average direct static stress is shown in Col. 4. A maximum static stress of 1.94 ksi compression was recorded in the northwest pile of pier 4 under the eastbound test locomotive, compared with a calculated stress of 1.63 ksi, which indicates that this pile was carrying 119 percent of the calculated stress, as shown in Col. 15, and for the same pier a minimum static stress of 1.17 ksi compression was recorded on two occasions in the center-east pile, indicating that this pile was carrying 72 percent of the calculated stress, as shown in Col. 9. On an overall average for all piles and all 5 runs, the recorded static stress varied from 5.6 percent greater to 11.2 percent less than the calculated static stress. It can be noted from Col. 23, that the average recorded static stress for the six piles in each pier was slightly less than the calculated.

In computing the maximum vertical static loads and the resulting stresses in the piles, the pier caps were assumed rigid enough to transmit the live load uniformly to the six piles in each pier.

Maximum Pile Loads and Total Impacts

The maximum recorded pile loads in kips for piers 2, 3 and 4 under the three conditions; timber bracing in place, timber bracing removed, and new steel bracing in place, are shown in the upper diagrams of Figs. 14 and 15. Values shown in Fig. 14 are for pier 3 with timber bracing in place, timber bracing removed, and steel bracing in place, while values in Fig. 15 are for pier 4 with timber bracing in place and removed, and for pier 2 with no bracing. The pile loads include live load plus impact and represent the average of six piles in each pier. The loads on the piles were arrived at by multiplying the average maximum stress on each pile by the load factor 26.67. In general, the maximum recorded pile load varied from 40 to 50 kips under the various conditions of bracing on the 3 piers. A study of Figs. 14 and 15 clearly indicates that the bracing had no effect on the magnitude of the pile loads, as would be expected. It can also be seen from these figures that there is a general increase in the maximum recorded pile load with an increase in locomotive speed. This is undoubtedly due to an increase in impact at the higher speeds.

The total impacts on the piles expressed as a percentage of the recorded static load are shown in the lower diagrams of Figs. 14 and 15. The total impact percentage is the increase in the load in the piles over that occurring at a slow-speed run for the same range of speeds and the same runs shown in the upper diagrams of these figures. The total impacts are a combination of speed effect and track and hammer-blow effects which occur on the beam spans and are carried down into the piles through the bearings and caps.

The total impacts in the piles are the average of the greatest simultaneous impacts recorded by the six piles in each pier for the same conditions under which the maximum pile loads were recorded—namely, timber bracing in place, timber bracing removed, and steel bracing in place. The greatest total impact was recorded in the piles of pier 4 with the timber bracing removed (see Fig. 15), and this amounted to 26.5 percent of the recorded static load at speeds of 49.5 and 54.5 mph. The greatest total impact in pier 3 was 24.3 percent at 50.6 mph, which was also recorded with the timber bracing removed. It can be seen from these diagrams that greater total impacts occurred in the piles which had the bracing removed. The bracing undoubtedly stiffened the piles and reduced the amount of vibration which was present when the pile length was unsupported. It should be kept in mind that massive bridge substructures are not designed for impact; however, an allowance of 25 percent of the live load was made for impact in designing these pile piers. It can be seen that an appreciable amount of impact does exist in the piles of this structure.

A study of these diagrams of total impacts indicates that there is a general increase in total impacts with an increase in locomotive speed.

The values for total impact in pier 3 with steel bracing in place were less than 9 percent in all but 2 runs, which would indicate that the steel bracing was effective to a certain degree in reducing impact; however, the steel bracing was originally included in these tests in order to study its effectiveness in reducing lateral sway in the piers.

Load Distribution to Piles

The distribution of the live load to the individual piles in piers 2, 3 and 4 for a full range of speeds is shown in the diagrams of Figs. 16 and 17. The load on each pile was determined from the maximum recorded stress read from the oscillograms simultaneously for the six piles in each pier. The load factor, 1 psi stress on the steel equals 26.67 lb axial load, was used to determine the load on the piles from the recorded stresses, and the results are shown in Cols. 3, 5, 7, 9, 11, and 13 of each diagram. The load on each pile was expressed as a percentage of the sum of the total load on each pier, and these percentages appear in Cols. 4, 6, 8, 10, 12 and 14 of the diagrams. The static loads shown represent the average of five slow-speed runs, and the curves shown at the bottom of each table illustrate the percentage distribution of load to each pile for the static runs and for an average of the six highest loads throughout the full range of speeds.

From the curves, using open circles for static loads (see Fig. 16) it can be seen that the percentage of static load carried by the piles in pier 3 varied from a minimum of 14.3 percent to a maximum of 19.5 percent. A perfect distribution would require that each pile take 1/6 or 16.7 percent of the total load on the pier, so it appears that there was good distribution to the piles for the static loads. The curves with open symbols shown on Fig. 17 illustrate the variation of load carried by the piles in piers 2 and 4. In these 2 piers the distribution varied from a minimum of 13.1 to a maximum of 20.5 percent in the piles of pier 4 with timber bracing removed. From this study it appears that the use of bracing on piers 3 and 4 had little or no effect on the distribution of load to the various piles. It can also be seen that the batter piles in each pier carried a full share of the load.

It can be seen from a study of the distribution curves for the average of the six highest loads throughout a full range of speeds (see dash curves with solid symbols on

Figs. 16 and 17) that for the higher loads caused by greater speeds, the load distribution is essentially the same as for static loads. This was especially true on pier 4 with timber bracing removed, as indicated by the curves in the lower right corner of Fig. 17.

Lateral and Longitudinal Bending in Piles

There was considerable variation in the recorded stresses at all speeds for the individual gages located at the ground sections on piers 2, 3 and 4. This variation is shown for a static and high-speed run in Fig. 9 for the 24 gages located at the ground section of pier 3. It can be seen from Fig. 9 that the compressive stresses in the center-east pile under an eastbound test train at a speed of 4.2 mph varied from — 1.32 ksi to — 1.70 ksi, with an average of — 1.49 ksi. A comparison of the four recorded stresses with the average indicates that the stresses do not vary across the section as a plane, so in determining the maximum bending stresses the difference between the largest stress and the average stress was taken as the bending stress. For example, the lateral bending in the center-east pile at a speed of 4.2 mph (see Fig. 9) was taken as the difference between — 1.70 ksi and the average of — 1.49 ksi, or — 0.21 ksi, which is 14.1 percent of the axial stress in the pile. This eccentric bending was to the south. The longitudinal bending in the center-east pile at a speed of 4.2 mph was taken as the difference between the maximum compressive stress in the longitudinal direction, which is — 1.58 ksi, and the average stress, which is — 1.49 ksi. The bending stress would therefore be — 0.09 ksi, which is 6.0 percent of the axial stress in the pile. This eccentric bending was to the east.

The lateral bending in the individual piles of piers 3 and 4 obtained under a full range of speeds is shown as a percentage of the recorded axial stress in the diagrams of Figs. 18 and 19. In these figures the solid circles illustrate the lateral bending in the individual piles of piers 3 and 4 with timber bracing in place, the solid triangles represent the lateral bending with timber bracing removed, and the solid squares represent the lateral bending with new steel bracing in place. All the bending stresses were recorded under normal operation of the test train, and the average bending for all runs is shown for each pile as indicated by the solid and dash lines. It can be seen from these diagrams that the lateral bending in the piles was quite large, especially in pile 2 in pier 3, where the average lateral bending with timber bracing removed was 37 percent. For some runs the lateral bending was as high as 108 percent of the recorded axial stress, as illustrated in the diagram for pile 6 in pier 4 with timber bracing removed (see Fig. 19). The use of timber bracing was effective in reducing the amount of lateral bending, especially in pier 3, where the lateral bending in five out of six piles was reduced to approximately one-half of what it was with the timber bracing removed (see Fig. 18). However, the difference in pier 4 was small. In all of the piles of piers 3 and 4 the lateral bending, in percent of the recorded axial stress, was lower with the timber bracing in place, as illustrated by the solid lines shown on the diagrams.

The longitudinal bending in the individual piles of piers 2, 3 and 4 obtained under a full range of speeds is shown as a percentage of the recorded axial stress in the diagrams of Figs. 20, 21 and 22. All the values shown on these figures were secured under an eastbound test train for normal operation. The maximum longitudinal bending occurred in pile 4 of pier 4 where the average longitudinal bending in percent of the recorded axial stress was 30.5 with timber bracing in place (see Fig. 22). In general, there appears to be no relation between the use of bracing and the magnitude of the longitudinal bending in the piles. A study of Figs. 20, 21 and 22 also indicates that there is no apparent relation between locomotive speed and longitudinal bending in the piles. The exact causes of the bending is not known, however, it could be the result of the beams in one span bearing near the edge of the cap, with the beams of the adjoining span bearing closer to the center of the cap. A study of the tabulated longitudinal bending stresses indicates that the bending was predominantly towards the east for over 90 percent of the test runs. This phenomenon may be the result of a longitudinal force applied to the piers through the span bearings due to the deflection of the spans under the eastbound locomotive.

Longitudinal and Lateral Forces

The testing of this structure with a special test train made it possible to secure data on the bending stresses in the piles resulting from a train crossing the bridge at various speeds under normal operating conditions, compared to the bending stresses produced by the same test train crossing the bridge with the brakes applied (service application of brakes). In addition, tests were made to determine the bending stresses in the piles resulting from stopping the train at various positions on the bridge by a hard application of the brakes, and then accelerating the train as rapidly as possible to determine the tractive effect from the locomotive drivers. In making these longitudinal force tests, the gages were placed on the piles near the ground line and just under the concrete cap on pier 3, as shown by Sections E–E and F–F in Fig. 7. In addition to the gages on the piles, gages were also placed longitudinally on the webs of the rails near the neutral axis, as shown by Sections C–C and D–D (see Fig. 7), to determine any longitudinal force carried by the rails.

Typical traces showing the general characteristics of the stresses produced in the piles and rails by stopping the test train on the bridge with a hard service application of the brakes are reproduced in Fig. 7. The position of the locomotive and part of the tender where they stopped on the bridge is shown in the "Elevation" at the right of the diagram. The typical traces, G1–G8, incl., located on the piles and rails were reproduced to a larger scale from the oscillogram secured under the test run marked "train position A". Traces G1 and G2, obtained with gages located on the rails at the west abutment, indicate that the rails started carrying longitudinal tensile stress when the brakes were first applied at a speed of approximately 4.32 mph, and that these stresses kept increasing until the forward movement of the train stopped 16 sec later. As soon as the train stopped, the tensile stresses in the rails over abutment 6 were reduced, but it can be seen that the structure continued to vibrate at a low frequency for about 2 sec and that a large part of the tensile stress remained in the rails after the structure stopped vibrating. While the rail gages over abutment 6 were recording longitudinal tensile stresses, gages G3 and G4 located over the east abutment were simultaneously recording longitudinal compressive stresses, and it can be seen from the typical traces that part of the compressive stresses were retained after the train stopped and the structure ceased vibrating. This stress retained in the rails returned to approximately zero after the entire train moved off the bridge; therefore, it is apparent that this retention of stress is the result of the entire structure yielding longitudinally in the direction of the train and being held in that position after the train stops by friction. For train position "A" the maximum tensile stress recorded in the rails at the west abutment at the instant the train stopped was + 3.30 ksi, while the maximum compressive stress at the east abutment was — 1.00 ksi. Thus, assuming uniform stress distribution over the entire cross section of the 112.25-lb rail and using the average stress recorded by the two rails at each end of the bridge, a tensile force of 62.8 kips was carried by the rails at the west abutment, while a compressive force of 19.8 kips was carried by the rails at the east abutment, or by summation of the two forces it can be seen that the total longitudinal force carried by the rails was 82.6 kips for this particular run.

Traces G5, G6, G7 and G8 on Fig. 7 were obtained from gages located on the center-east pile of pier 3, as shown by Sections E–E and F–F, and it can be seen that their action was similar to that of the rails, except that the pile was taking vertical load as well as longitudinal load as soon as the first wheel of the locomotive came onto the span between piers 3 and 4. For this particular run marked "train position A", the west side of the center-east pile near the concrete cap, gage G6, was stressed in bending to 2.13 ksi compression by the braking force, while the east side at the same section, gage G5, was stressed to 0.85 ksi tension. The gages near the ground line simultaneously recorded 0.13 ksi tension on the west side of the pile and 1.10 ksi compression on the east side. This reversal of stress between the cap and ground sections indicates that the pile is fixed against rotation at the concrete cap and some place in the ground, thus any longitudinal displacement of the cap towards the east induces tensile stresses on the east side of the pile near the cap and on the west side of the pile near the ground line. Therefore, a point of contraflexure, or point of zero moment, exists somewhere between the concrete cap and the ground line, depending primarily on the location of the point of fixity of the pile in the ground.

Before it was possible to compute equivalent static longitudinal or lateral forces on the piers from the bending stresses induced in the piles near the ground line, it was first necessary to make an analysis to determine where the piles were fixed below the ground line and consequently locate the point of contraflexure of the piles in piers 3 and 4. An analysis for the point of contraflexure in the piles of pier 3 is shown on Fig. 23. Gages were located at the top, bottom and mid-height on the southeast and center-east piles, as shown on the "End View" in Fig. 23. The lateral and longitudinal bending stresses were read from the oscillograms simultaneously for all the gages located at the three sections on the two piles. For this analysis 6 eastbound runs varying in speed from 5 to 58 mph were used, and the readings from the oscillograms were made with the second driver of the locomotive over the test pier. The bending moment in ft-kips was computed from the bending stresses, using the flexure formula and the moment of inertia of the transformed pile section. The transformed moment of inertia in terms of concrete was found to be $I_t = 2448$ in^4, using $n = 7$. The modulus of elasticity of steel was assumed equal to 30,000,000 psi. The bending moment curves for the southeast and center-east piles are shown in Fig. 23 for the lateral and longitudinal planes, and to the right of these diagrams the average curve and average point of contraflexure, or point of zero moment, is shown for both planes. It can be seen that the average point of contraflexure due to lateral bending was 13 ft from the bottom of the concrete cap, and that this is in good agreement with the average point of contraflexure due to longitudinal bending, namely, 12.6 ft from the bottom of the cap. The diagram in the lower left corner of Fig. 23 illustrates the use of the point of contraflexure in determining equivalent static lateral and longitudinal forces on pier 3. The average of the lateral and longitudinal points of contraflexure was found to be 12.8 ft from the cap, and this value was assumed for all the piles in pier 3. Assuming the piles fixed against rotation at the cap, the point of contraflexure must occur half way between the point of fixity at the cap and the point of fixity in the ground. Therefore, on the basis of this analysis of the two piles, it seems logical to assume that the piles of pier 3 are fixed on a plane about 5.6 ft below the ground line, the usual assumption being 6 ft, and the point of contraflexure is therefore located 6.74 ft above the gage lines near the ground. Consequently, a force, F, applied at the point of contraflexure with a moment arm of 6.74 ft will produce the moment, M_3, which was determined from the bending stresses in the piles. This force applied at the point of contraflexure is equivalent to a static lateral or longitudinal force applied to the pier by the locomotive. Since readings were taken at the ground lines on piers 3 and 4 under the locomotive running at normal operation, under the locomotive operating with a service application of the brakes, and under the locomotive braking to a stop on the bridge, it was possible to determine the equivalent static lateral and longitudinal forces on piers 3 and 4 from this type of analysis. These lateral and longitudinal forces are shown on Figs. 24 and 25.

A study of the oscillograms secured under passage of the test train with gages on the piles at the ground line indicated that the locomotive was producing a sinusoidal lateral force in the piers, as shown by the typical oscillogram in Fig. 8. This sinusoidal lateral force started when the locomotive reached the first span and increased to a maximum when the drivers were over the test pier. The effect of this lateral force is to bend the pile about an axis parallel to the track, with a resulting increase in compression on one side of the pile and a simultaneous decrease in compression on the other side. It can be seen from Fig. 8 that at any particular time, such as that shown by the vertical line labeled "position of train for max. lateral bending in east piles", the gages on the north side of the piles, A4, A8 and A12, indicate an increase in compression of 1.18, 1.01 and 1.03 ksi, respectively, while the gages on the south side of the piles, A2, A6 and A10, indicate a decrease in compression of 0.68, 0.73 and 0.88 ksi, respectively. These bending stresses in the piles, which were determined by drawing the envelope curves and the "mean stress curve" as described previously in this report, are shown in the upper diagrams on Fig. 24. The equivalent static lateral forces computed from these bending stresses are shown along with the AREA design force in the lower diagrams of Fig. 24. It can be seen that all values were less than the AREA design force of 20 kips and that the maximum computed force was 4.50 kips. The timber bracing was effective in reducing the lateral forces on pier 3 from an average of about 2.90 kips without timber bracing down to approximately 1.76 kips with timber bracing in place; however, the steel bracing was not effective in reducing the lateral forces. In general, there appears to be an increase in lateral force with an increase in speed, as can be seen from the lateral forces in pier 3 (see Fig. 24).

The longitudinal bending stresses induced in the piles of the various piers under the test train crossing the bridge with normal operating conditions, as previously discussed and shown in Figs. 20, 21 and 22, are believed to be the result of eccentric loading of the piles. It is apparent that the application of a longitudinal force, such as that produced by the braking of a train, would either increase or decrease the bending stresses in the piles, depending upon the direction of the eccentric loading. To determine whether the application of the brakes on the test train actually increased or decreased the bending stresses in the piles, the equivalent static forces required to produce the bending stresses were calculated as discussed previously and are shown in the diagrams on Fig. 25. For example, the equivalent static longitudinal force values shown by the solid symbols in Fig. 25 were calculated from the bending stresses in the piles secured under normal operation of the test train over the bridge, while those shown by the open circles were calculated from the bending stresses secured with the test train crossing the bridge at the speeds indicated, but having the brakes applied before reaching the bridge. It can be seen that there is little difference in the equivalent static longitudinal forces between the two methods of operation, except at the lower speeds of about 1.6 and 2.1 rps, where there is some indication of an increase in equivalent static longitudinal force with the train braking. The equivalent static longitudinal force values shown by the open triangles at zero speed were secured with the train stopping on the bridge, as explained previously. It can be seen from the longitudinal force diagram for pier 3 in Fig. 25 that the equivalent static longitudinal forces on the pier secured under braking to a stop on the bridge were not appreciably higher than those obtained under normal operation or under service application of brakes. The diagrams in Fig. 25 indicate that the maximum equivalent static longitudinal force carried by piers 3 and 4 was approximately 2.25 kips, compared with the AREA design specification force of 39 kips (15 percent of pier reaction). However, it should be pointed out, as shown by the note in Fig. 25, that the rails were carrying longitudinal forces at the instant the train stopped, which varied from 54.6 to 127.5 kips.

Stresses in Timber Bracing

The maximum tensile and compressive stresses in the timber bracing members on pier 3 were measured simultaneously for a full range of speeds, and the results of this study are shown in the diagrams of Fig. 26. The solid circles represent the maximum average stress, tensile or compressive, recorded in the 3-in by 12-in timber bracing attached to the east piles, while the open circles show the maximum average stress, tensile or compressive, recorded in the bracing on the west piles. A maximum tensile stress of 105 psi was recorded in the bottom diagonal bracing on the east piles, as shown in the diagram for Section 11–11, and this stress would be equivalent to a load of 3780 lb in the bracing. A maximum compressive stress of 112 psi was recorded in the top diagonal on the west piles, as shown in the diagram for Section 8–8. This stress represents a load of 4030 lb in the bracing. It can be seen from these diagrams that there is a general increase in stress in the timber bracing with an increase in speed, indicating that the bracing is carrying stresses induced by the lateral forces on the pier. Since it was found that the lateral forces increased with an increase in speed, it is reasonable to expect an increase in the bracing stresses with an increase in speed. It is interesting to note that there was little or no reversal of stress in the diagonal bracing at Sections 8–8 and 10–10 (see Fig. 26). The maximum stresses at Section 8–8 were predominantly compressive, while the maximum stresses at Section 10–10 were predominantly tensile. Since a theoretical analysis of the bracing stresses was not made, an explanation of this behavior is not readily available. It should be pointed out that all bracing on both piers 3 and 4 was tightened before any testing was begun.

SOIL DATA

Two soil borings, located as shown on the "Plan" in Fig. 5, were taken after the tests were completed, and the samples of soil from the borings were classified and analyzed. These soil data are shown in Fig. 27. All soils tested had medium to low plasticity, and the compressive strength varied from 2.2 to 9.5 tons per sq ft. No correlation was made between this soil information and the point of fixity of the piles in the ground. Test data from many more bridges of this type would be required before an intelligent analysis could be made; therefore, these soil data are included only as information for future reference.

PILE DRIVING RECORD

The pile driving record for the 18 piles in piers 2, 3 and 4 are included in Fig. 28 as information for future reference. All piles were driven by the NYC&StL bridge and building gang, using a single-acting, 5000-lb, No. 1 Vulcan hammer with a 3-ft stroke. The piles were ordered in 40-ft lengths and were extended by splicing before being driven to tabulated penetration.

ACKNOWLEDGMENTS

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are indebted to the officers of the NYC&StL and the Armco Steel Corporation for their cooperation in conducting these tests.

CONCLUSIONS

The tests on this bridge afforded an opportunity to analyze the effect of railroad loading on a relatively new and economical type of railroad structure.

From the data as found in these tests the following observations can be made:

1. The static stresses in the beams were about 80 percent of the calculated stresses, which is in line with previous tests on short span bridges.

2. The impact stresses in the beams were well below the AREA design requirements. This confirms previous tests showing lower impacts in spans resting on resilient supports than in spans resting on massive supports.

3. The live load was about equally distributed to the piles in each pier, the batter piles taking their full share of the load.

4. The impacts in the piles reached a maximum of 26 percent of the live-load stresses.

5. The lateral bending stresses in the piles reached a maximum of 1.08 ksi. The equivalent lateral force on one pier necessary to produce this stress is about 4.5 kips, well below the AREA design force of 20 kips. Neither type of bracing used on these piers was considered satisfactory. It seems evident that the application of suitable bracing would result in a more rigid structure.

6. The highest longitudinal bending stress measured was 0.6 ksi. The greatest longitudinal force taken by one pier was about 2.25 kips, considerably below the AREA design force of 39 kips (15 percent of the pier reaction).

The longitudinal forces on the structure due to braking were not much higher than those from normal operation. The longitudinal forces in the rails at the abutment due to braking varied from 55 to 125 kips.

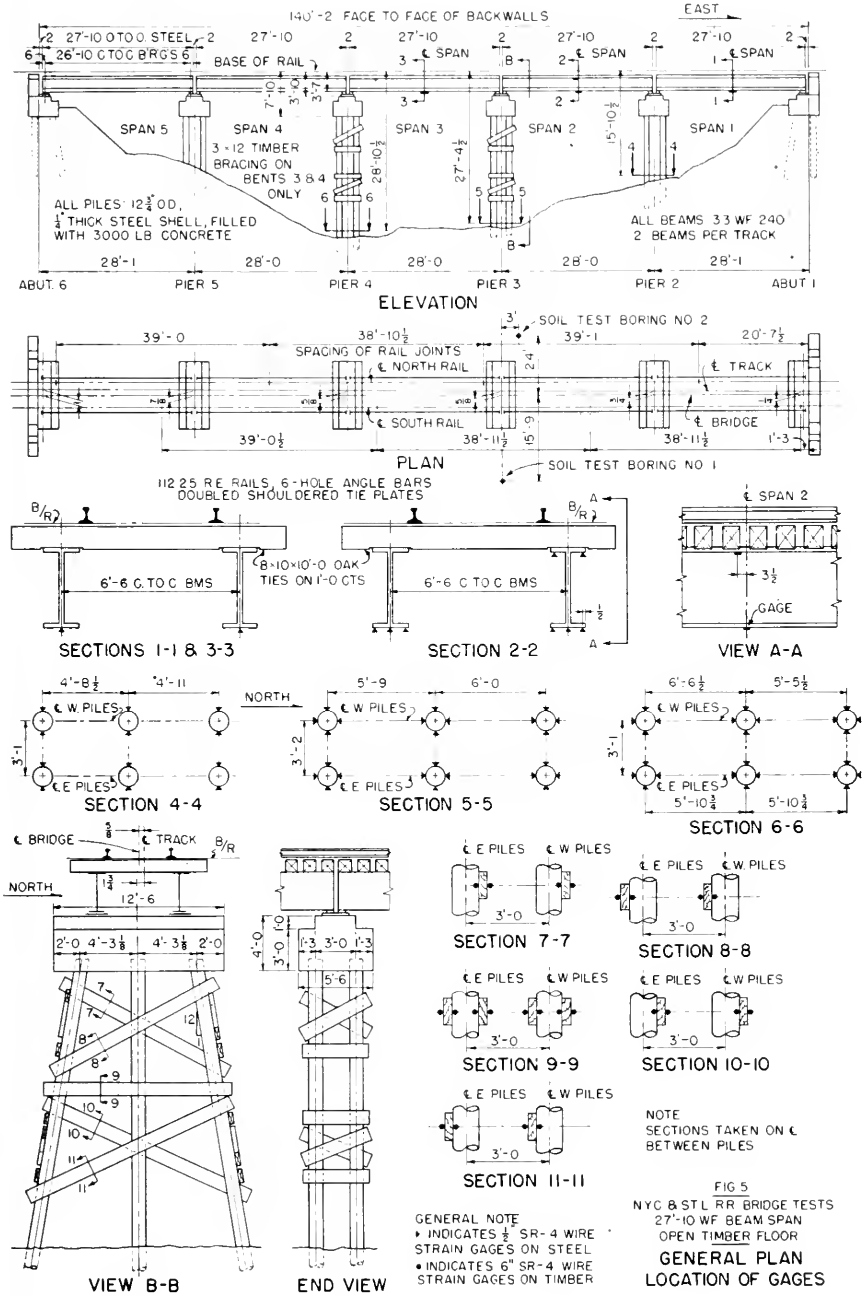


FIG 5
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPAN
OPEN TIMBER FLOOR
GENERAL PLAN
LOCATION OF GAGES

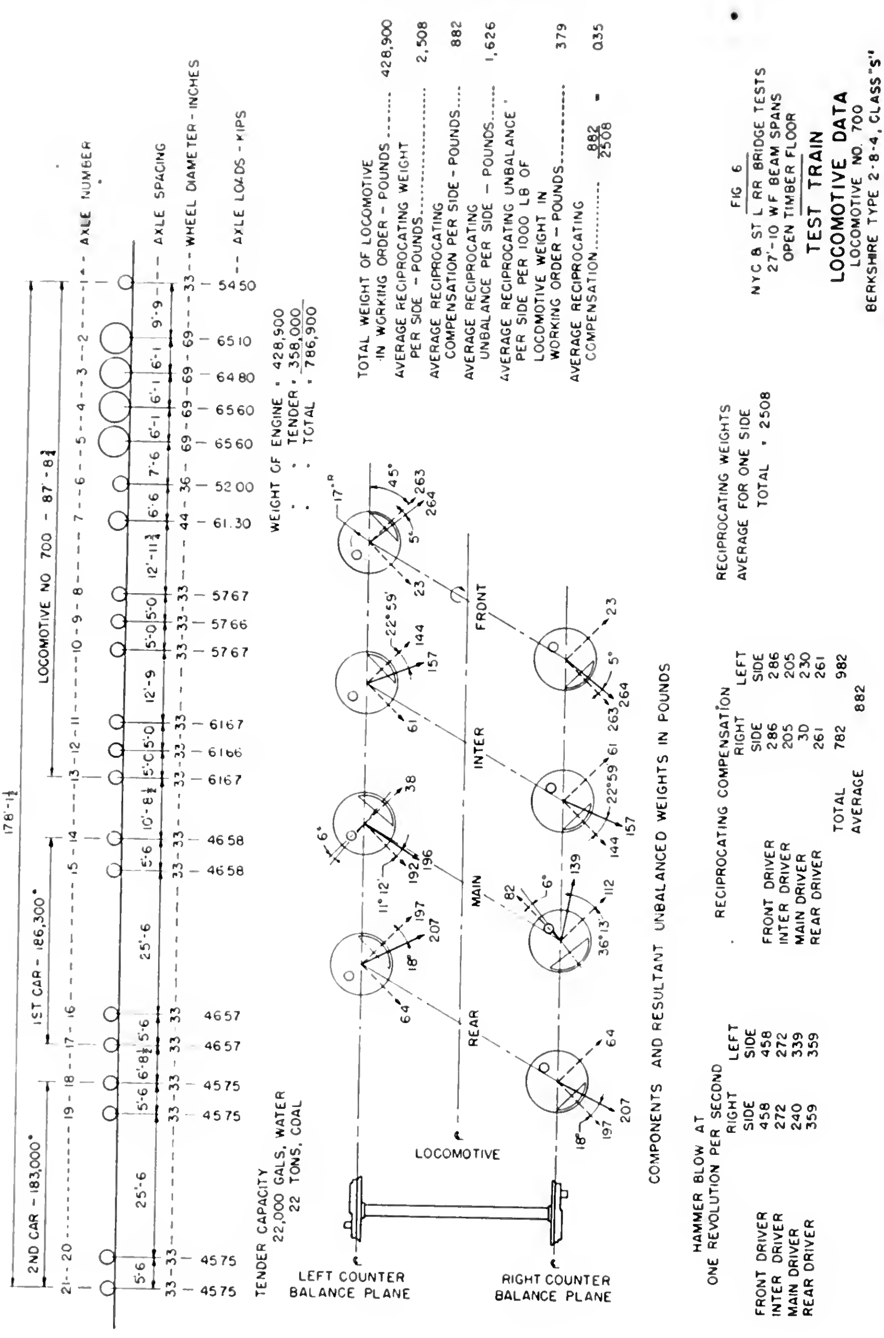
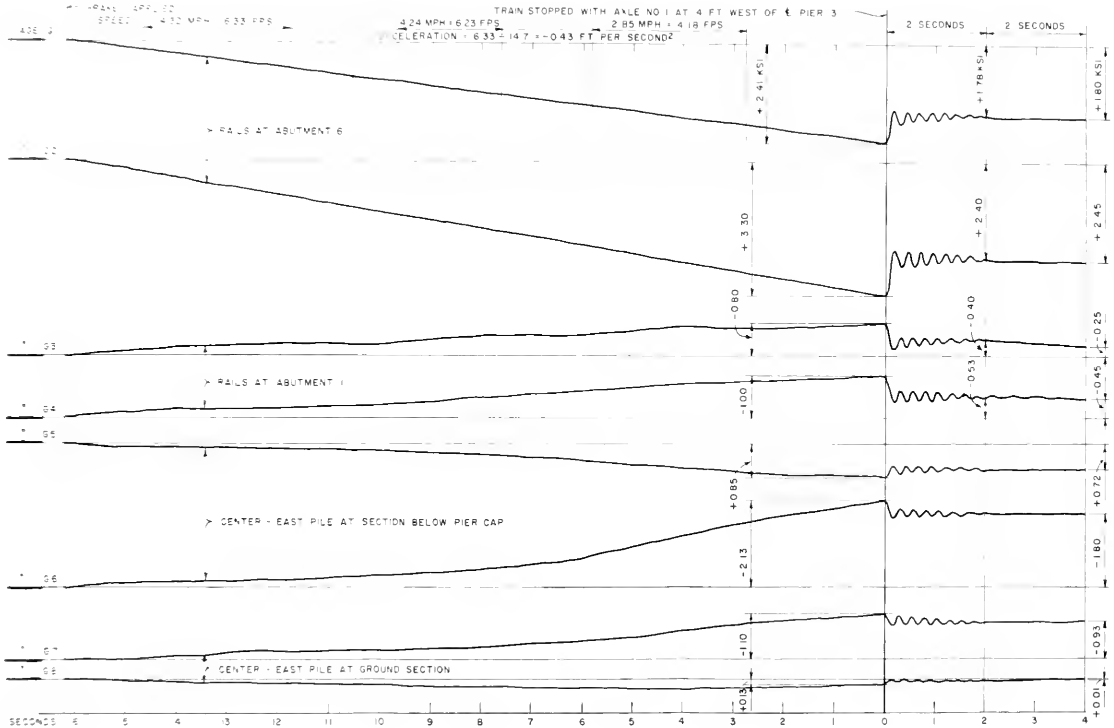
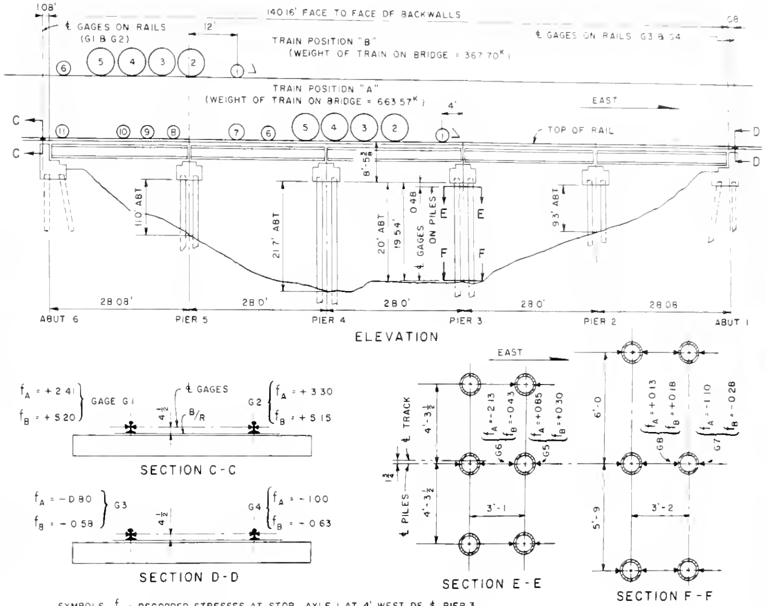


FIG 6
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR

TEST TRAIN
LOCOMOTIVE DATA
LOCOMOTIVE NO. 700
BERKSHIRE TYPE 2-8-4, CLASS "S"



TYPICAL RECORDED TRACES FOR TRAIN POSITION "A"



SYMBOLS f_A - RECORDED STRESSES AT STOP, AXLE 1 AT 4' WEST OF ℄ PIER 3
f_B - " " " " , " 1 " 12' EAST " " " 5
▼ - ½-IN SR-4 GAGES, (DOUBLE GAGES PLACED LONGITUDINALLY ON RAILS)

NOTES RAILS NO 11225 RE, AREA = 11.02 SQ IN, N.A. = 2.98" FROM BASE
PILES STEEL SHELL 12¾-IN O.D., ¼-IN THICK,
FILLED WITH CONCRETE (n = 7)
STRESSES ARE GIVEN IN KSI, + INDICATES TENSION, − INDICATES COMPRESSION

FIG 7
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR

TYPICAL OSCILLOGRAM
BRAKING EFFECT

LOCOMOTIVE - BERKSHIRE TYPE 2-8-4
NYC & ST L RR, CLASS 'S', NO 700

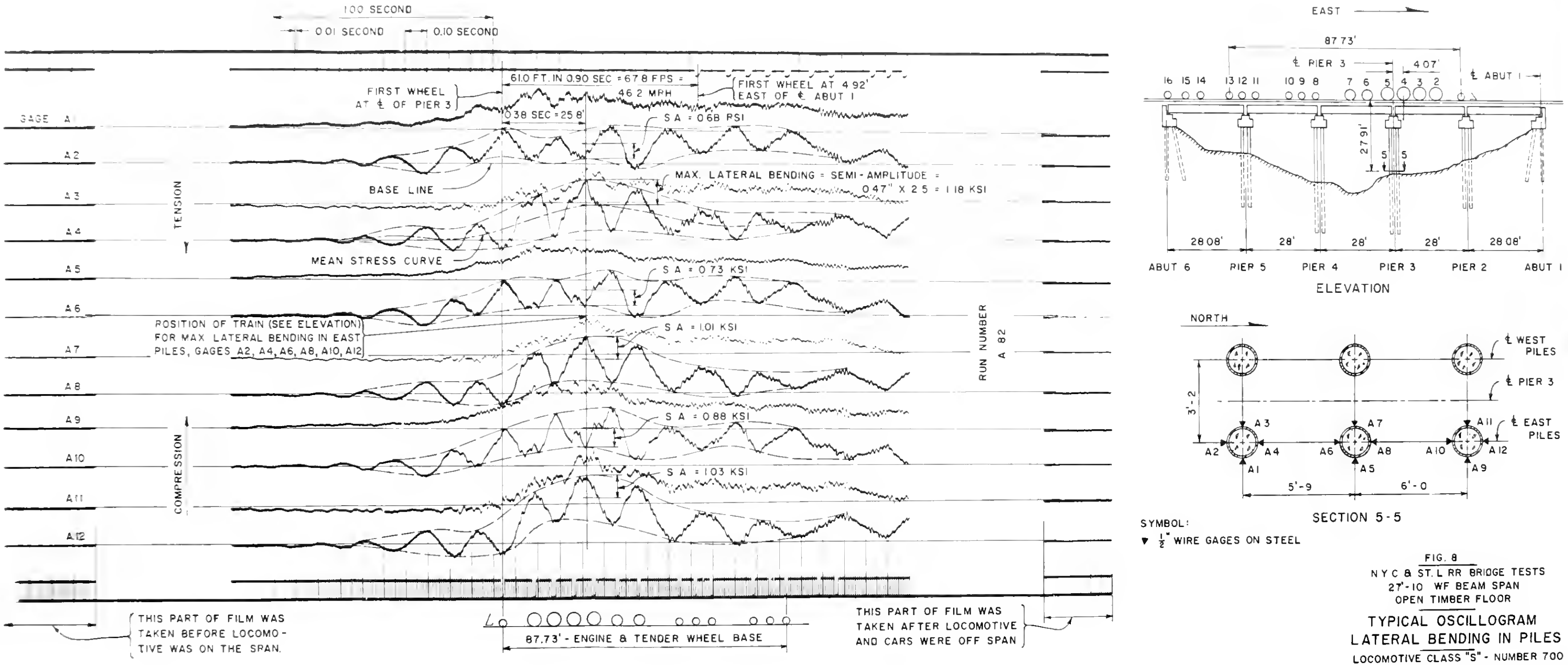
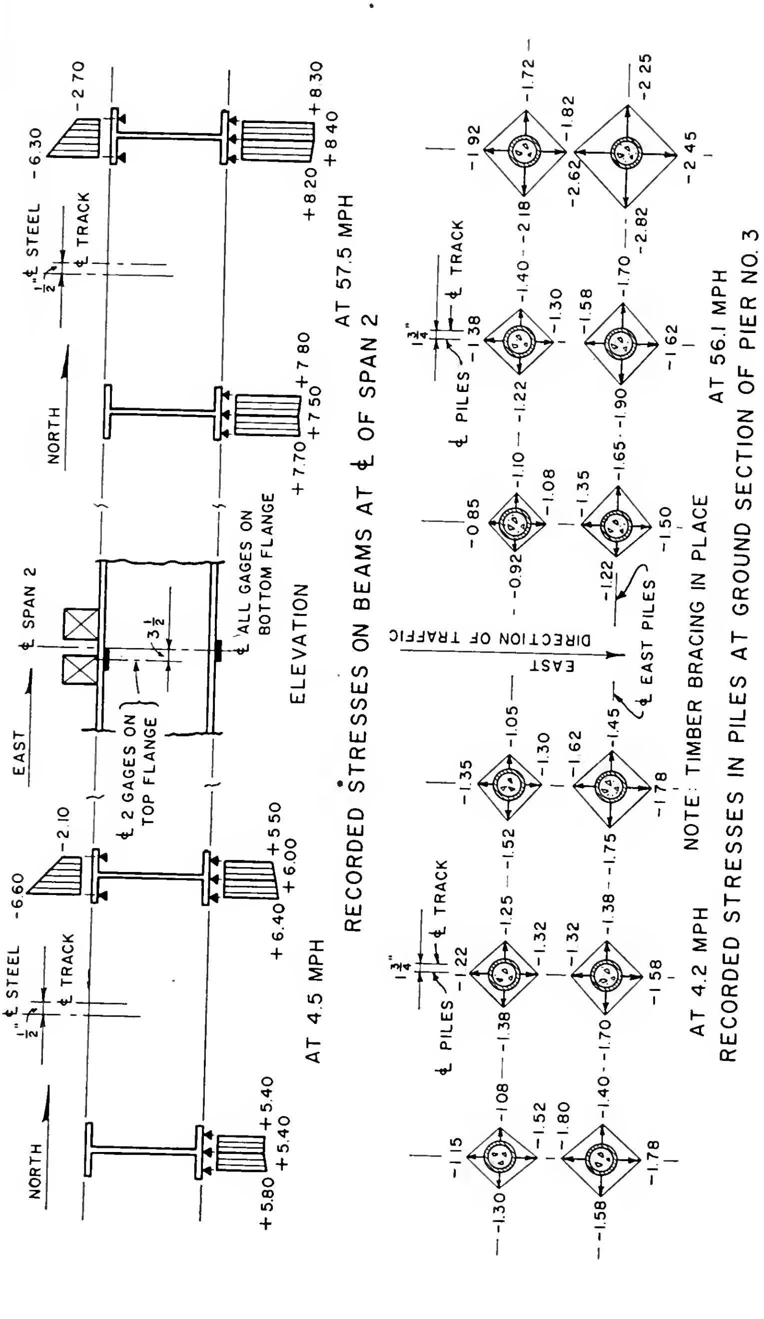


FIG. 8
N Y C & ST. L RR BRIDGE TESTS
27'-10 WF BEAM SPAN
OPEN TIMBER FLOOR

TYPICAL OSCILLOGRAM
LATERAL BENDING IN PILES

LOCOMOTIVE CLASS "S" - NUMBER 700
BERKSHIRE TYPE - 2-8-4



NOTE: STRESSES ARE GIVEN IN KSI
+ INDICATES TENSION
- " COMPRESSION

FIG. 9
NY C & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPAN - OPEN TIMBER FLOOR
VARIATION OF RECORDED MAXIMUM STRESSES

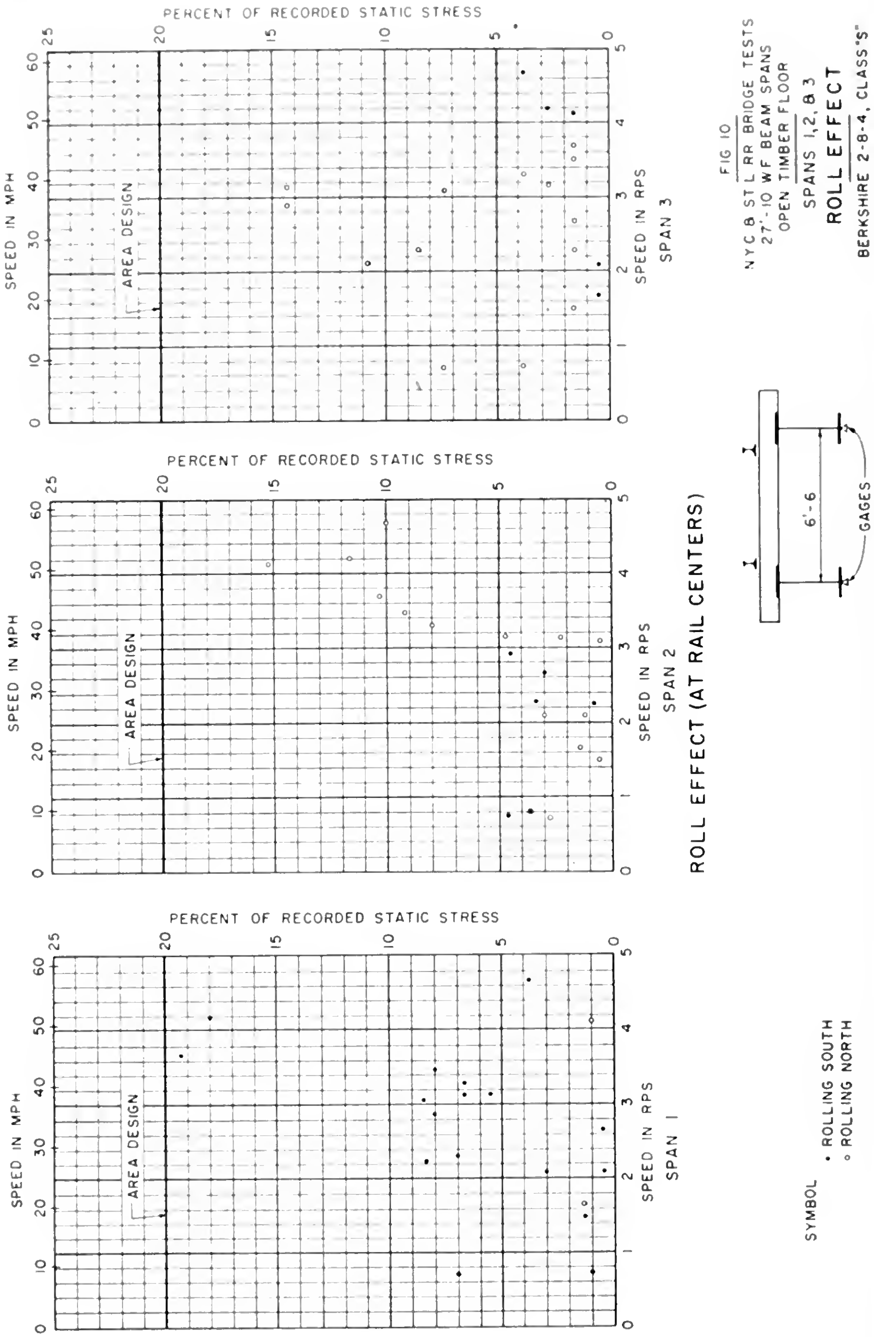


FIG 10
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
SPANS 1, 2, & 3
ROLL EFFECT
BERKSHIRE 2-8-4, CLASS "S"
ROLL EFFECT (AT RAIL CENTERS)
PERCENT OF RECORDED STATIC STRESS
SPEED IN MPH
SPEED IN RPS
AREA DESIGN
SPAN 1
SPAN 2
SPAN 3
6'-6
GAGES
SYMBOL
• ROLLING SOUTH
∘ ROLLING NORTH

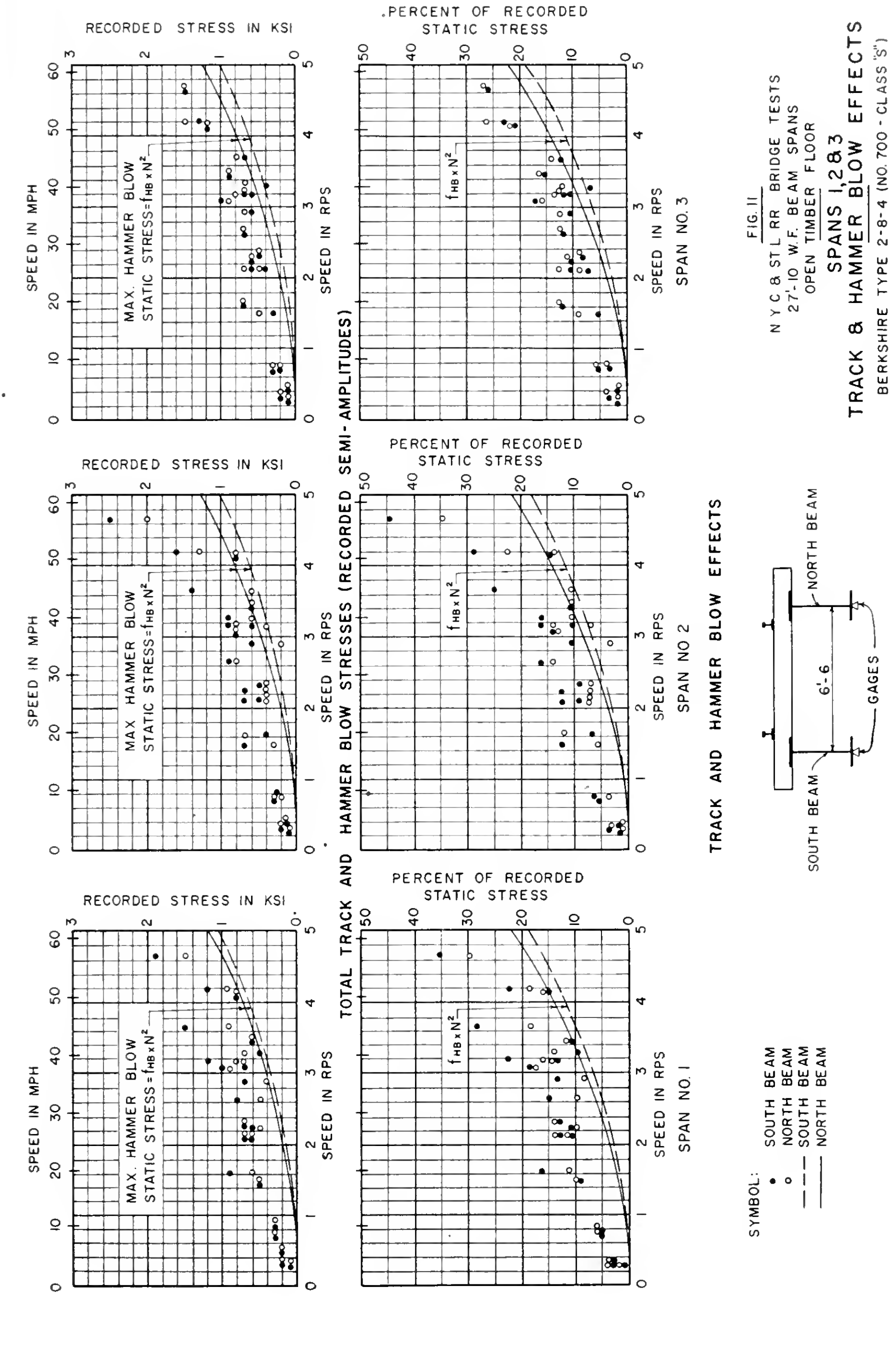


FIG. 11
N Y C & ST L RR BRIDGE TESTS
27'-10 W.F. BEAM SPANS
OPEN TIMBER FLOOR
SPANS 1, 2 & 3
TRACK & HAMMER BLOW EFFECTS
BERKSHIRE TYPE 2-8-4 (NO. 700 - CLASS 'S')

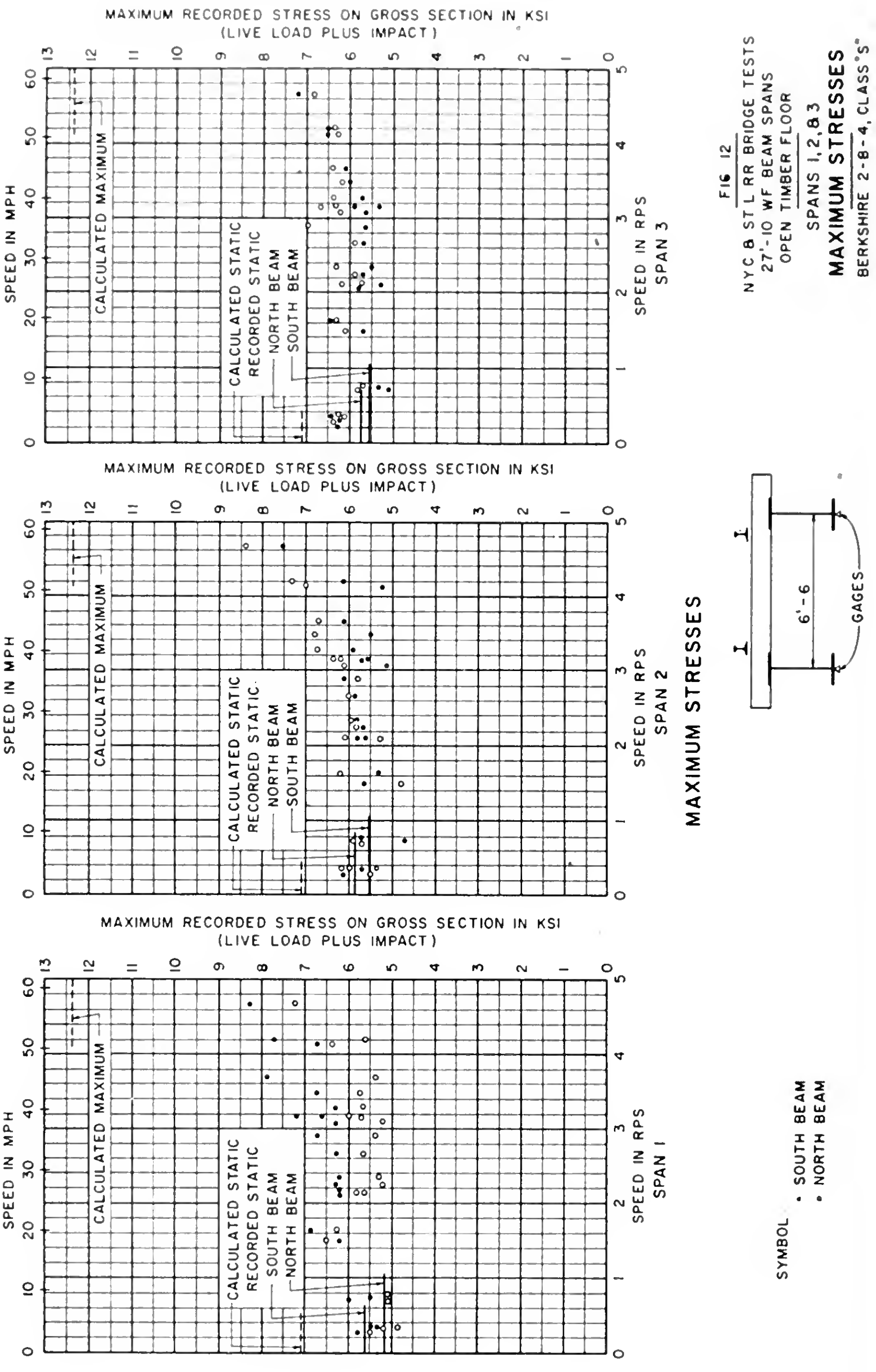


FIG 12
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
SPANS 1, 2, & 3
MAXIMUM STRESSES
BERKSHIRE 2-8-4, CLASS "S"

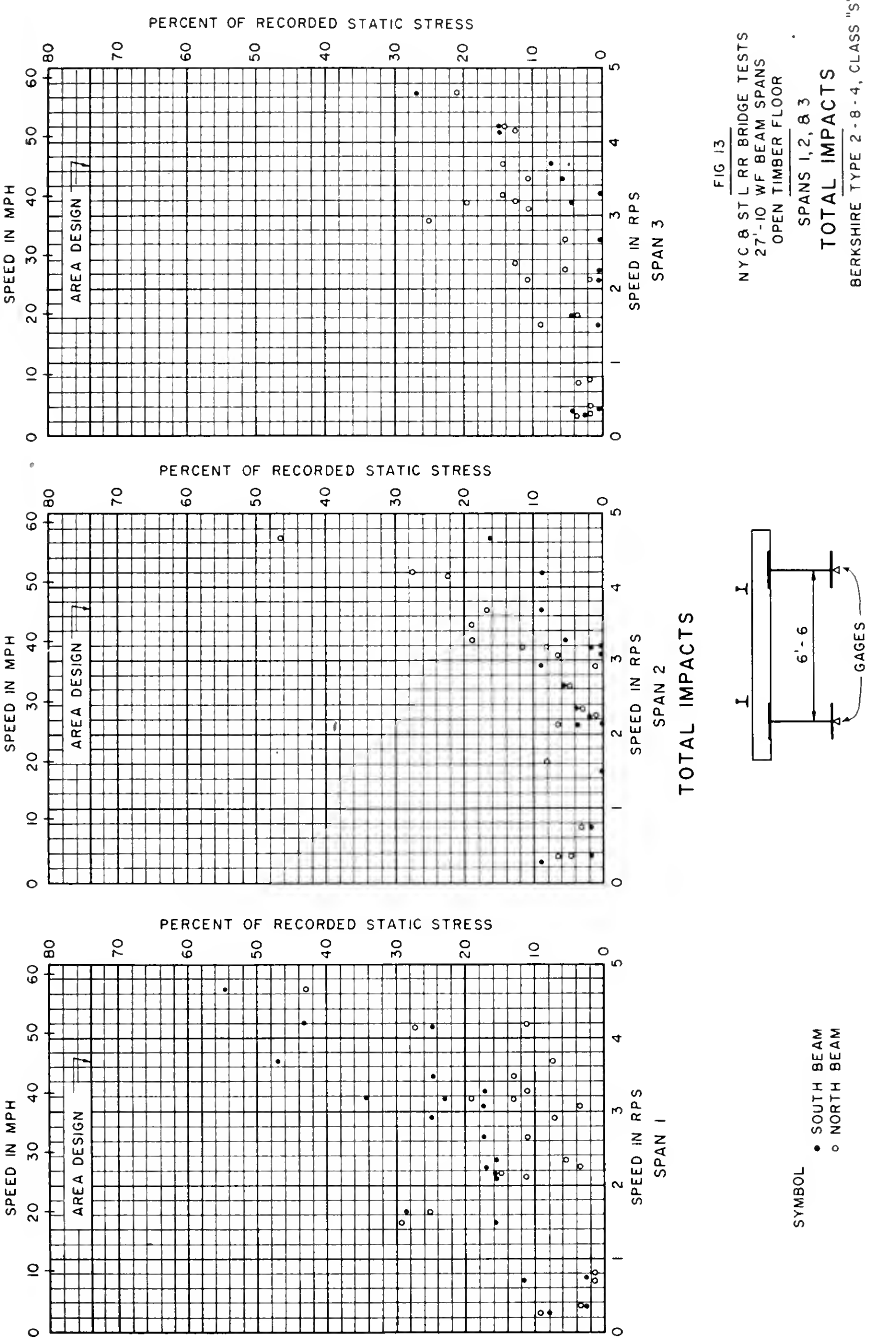


FIG 13
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
SPANS 1, 2, & 3
TOTAL IMPACTS
BERKSHIRE TYPE 2-8-4, CLASS "S"

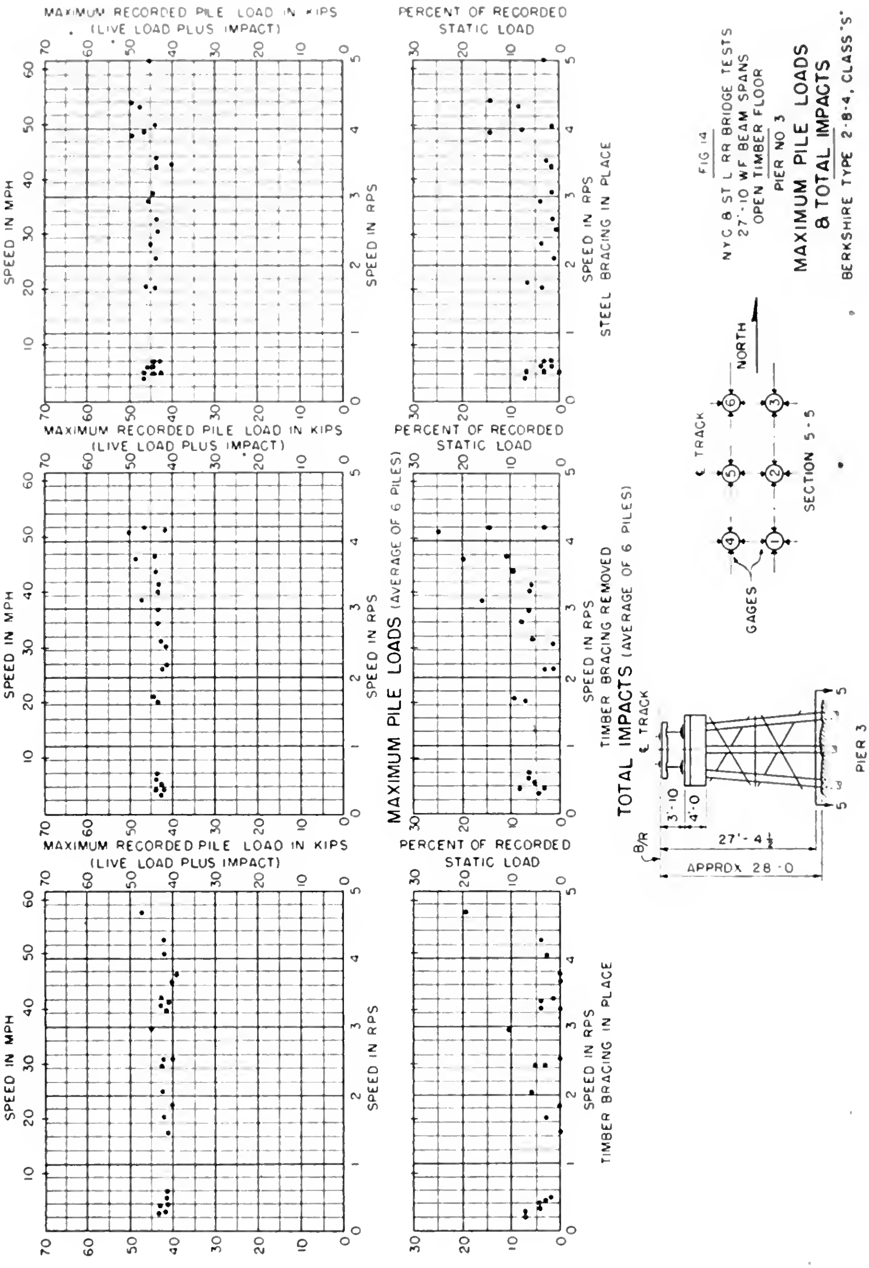


FIG 14
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIER NO 3
MAXIMUM PILE LOADS & TOTAL IMPACTS
BERKSHIRE TYPE 2-8-4, CLASS 'S'

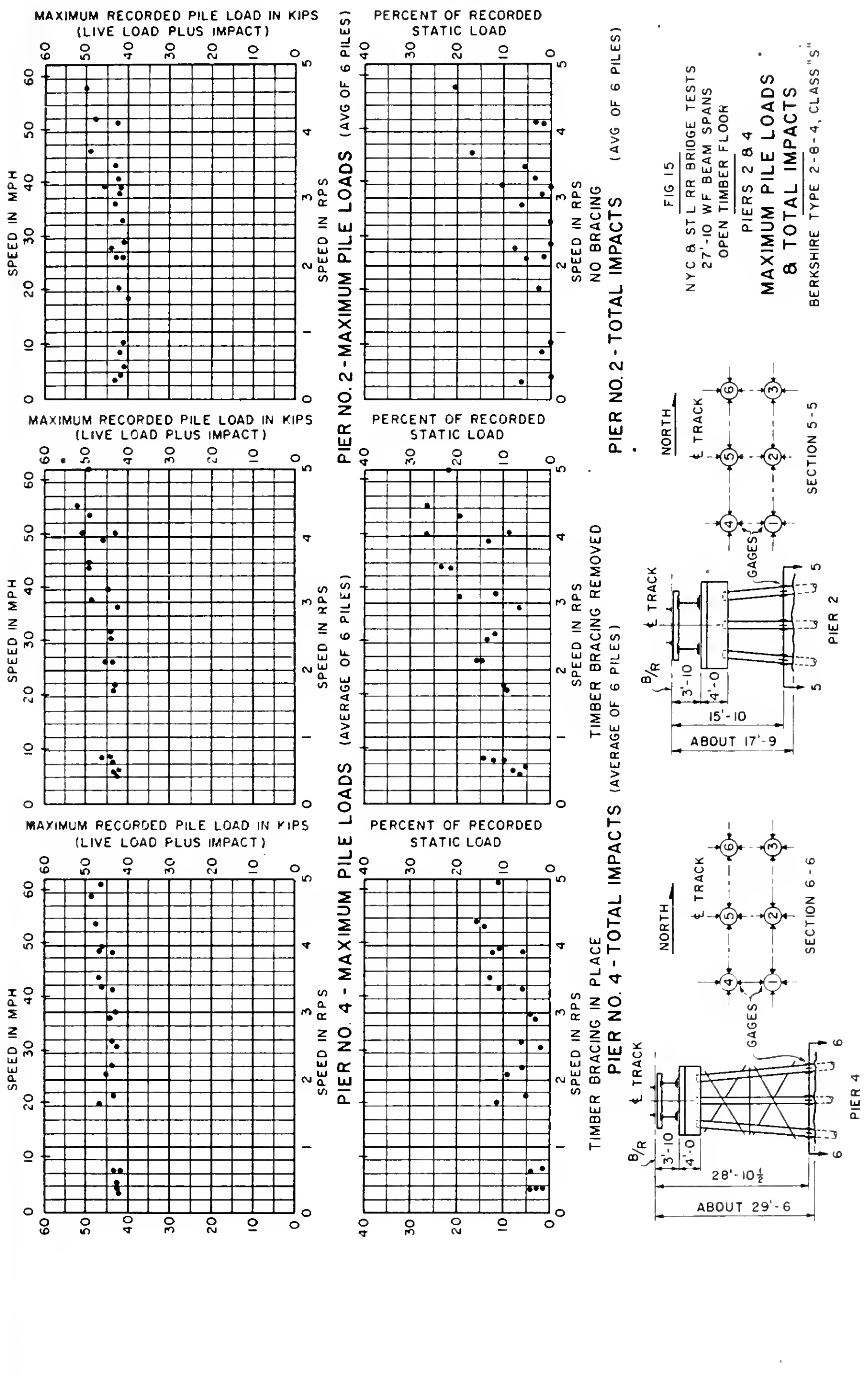
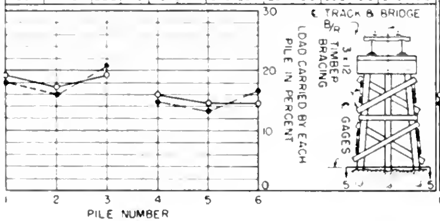


FIG 15
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIERS 2 & 4
MAXIMUM PILE LOADS & TOTAL IMPACTS
BERKSHIRE TYPE 2-8-4, CLASS "S"

DISTRIBUTION OF LOAD TO INDIVIDUAL PILES OF PIER NO. 3 - CALCULATED AVERAGE LOAD PER PILE = 43.4 KIPS

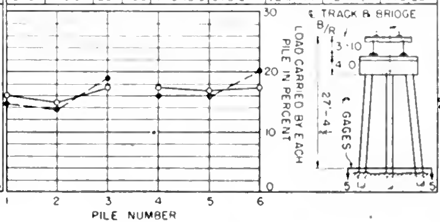
TIMBER BRACING IN PLACE

Locomotive Speed-MPH	Recorded Avg Load per Pile Kips	Pile 1 Load in Kips	Pile 1 Percent of Total Load	Pile 2 Load in Kips	Pile 2 Percent of Total Load	Pile 3 Load in Kips	Pile 3 Percent of Total Load	Pile 4 Load in Kips	Pile 4 Percent of Total Load	Pile 5 Load in Kips	Pile 5 Percent of Total Load	Pile 6 Load in Kips	Pile 6 Percent of Total Load
COL 1	2	3	4	5	6	7	8	9	10	11	12	13	14
STATIC	36.9	42.4	19.2	37.9	17.1	43.0	19.5	34.4	15.6	31.7	14.3	31.7	14.3
3.0	39.6	46.6	19.6	40.3	17.0	45.3	19.1	38.4	16.2	33.1	13.9	34.1	14.2
3.6	39.4	47.0	19.8	39.0	16.6	44.8	18.9	38.7	16.3	33.6	14.2	33.6	14.2
4.2	38.4	43.8	19.0	40.0	17.4	44.0	19.1	33.6	14.6	34.4	14.9	34.7	15.0
4.4	38.5	45.9	19.9	40.3	17.5	45.9	19.9	34.1	14.8	31.5	13.5	33.1	14.4
5.2	37.9	46.4	20.4	40.3	17.7	45.6	20.1	32.0	14.1	31.5	13.9	31.7	13.8
6.0	37.8	45.4	20.0	32.8	14.6	40.6	17.9	37.9	16.7	35.0	15.4	35.0	15.4
17.5	37.0	42.4	19.0	39.0	17.5	43.0	19.4	33.1	14.9	31.2	14.1	33.4	15.1
20	37.9	37.6	16.5	39.0	17.1	50.4	22.2	31.8	14.0	31.2	13.7	37.6	16.5
22.3	36.7	37.9	17.2	38.7	17.6	47.5	21.6	27.2	12.3	29.1	13.2	39.8	18.1
25.0	38.7	43.5	18.7	38.9	16.7	43.3	18.6	38.7	16.7	32.5	14.0	35.5	15.3
29.7	38.7	39.7	17.1	36.0	15.5	45.6	19.7	36.9	15.9	34.4	14.8	39.5	17.0
29.8	37.9	48.5	21.4	40.6	17.8	44.0	19.4	35.7	15.7	30.2	13.3	28.3	12.4
31.5	36.1	37.9	17.5	39.2	18.2	48.0	22.1	30.9	14.2	26.9	12.4	33.9	15.6
36.4	40.6	45.1	18.5	42.4	17.4	49.3	20.2	35.2	14.5	34.1	14.0	37.6	15.4
39.4	37.0	38.1	17.2	34.9	15.6	42.4	19.1	37.9	17.1	33.1	14.9	35.7	16.1
40.1	38.1	38.7	16.9	36.3	15.9	45.6	20.0	37.1	16.3	31.0	13.5	39.8	17.4
40.7	38.3	44.8	19.4	40.0	17.3	47.0	20.4	34.7	15.1	31.5	13.6	37.8	14.2
41.4	37.3	32.0	14.3	37.8	16.0	48.0	21.4	32.5	14.5	32.3	14.4	43.3	19.4
44.3	36.3	36.3	16.6	32.3	14.8	39.2	18.0	38.5	17.7	35.2	16.1	36.5	16.8
46.0	35.5	30.4	14.2	34.4	16.2	47.5	22.3	34.1	16.1	32.0	15.0	34.4	16.2
50.0	38.1	37.6	16.4	37.1	16.3	49.6	21.7	30.7	13.4	33.6	14.7	40.0	17.5
51.7	38.2	36.6	15.9	39.0	17.1	51.5	22.5	31.8	13.8	31.0	13.5	39.5	17.2
56.1	44.0	38.2	14.5	45.4	17.2	67.8	25.7	26.4	10.0	35.2	13.3	51.0	19.3



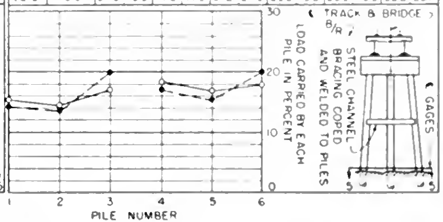
BRACING REMOVED

Locomotive Speed-MPH	Recorded Avg Load per Pile Kips	Pile 1 Load in Kips	Pile 1 Percent of Total Load	Pile 2 Load in Kips	Pile 2 Percent of Total Load	Pile 3 Load in Kips	Pile 3 Percent of Total Load	Pile 4 Load in Kips	Pile 4 Percent of Total Load	Pile 5 Load in Kips	Pile 5 Percent of Total Load	Pile 6 Load in Kips	Pile 6 Percent of Total Load
COL 1	2	3	4	5	6	7	8	9	10	11	12	13	14
STATIC	40.7	39.2	16.0	36.0	14.7	43.2	17.7	42.7	17.5	40.5	16.6	42.7	17.5
3.5	42.4	41.9	16.4	38.4	15.1	45.9	18.0	41.1	16.2	44.2	17.4	42.9	16.9
4.4	43.6	43.7	16.7	42.4	16.2	48.5	18.5	44.5	17.0	38.9	14.9	43.7	16.7
4.7	42.2	41.3	16.3	36.5	14.4	44.1	17.5	45.4	18.0	42.9	16.9	42.9	16.9
5.2	42.5	37.8	14.8	35.5	13.9	42.7	15.8	47.2	18.5	42.9	16.8	48.8	19.2
6.1	43.1	44.8	17.3	42.1	16.3	50.1	19.4	41.6	16.0	39.5	15.2	40.5	15.8
6.7	43.1	42.9	16.6	38.9	15.2	46.4	18.1	45.0	17.6	42.4	16.5	42.7	16.0
19.7	43.5	37.8	14.5	39.7	15.2	49.6	19.1	39.5	15.1	42.7	16.4	51.5	19.7
20.5	44.3	39.7	15.0	40.5	15.2	51.2	19.3	41.6	15.7	42.7	16.1	50.1	18.7
26.0	42.0	40.5	16.1	37.1	14.7	44.9	17.8	43.8	17.4	40.5	16.1	45.1	17.9
26.2	41.2	38.9	15.7	37.9	15.3	47.2	19.1	40.3	16.3	38.9	15.7	44.2	17.9
30.4	41.0	37.8	15.4	35.5	14.4	45.9	18.6	42.7	17.4	38.9	15.8	45.3	18.4
31.2	42.3	42.9	16.8	37.6	14.7	44.3	17.4	45.3	17.8	41.4	16.2	43.4	17.1
34.4	43.6	34.1	13.0	35.2	13.5	45.0	17.2	45.3	17.3	48.5	18.5	53.4	20.5
36.7	43.4	33.1	12.8	35.2	13.5	48.0	19.4	43.0	16.5	45.9	17.6	55.3	21.2
38.5	47.0	37.3	13.2	37.6	13.3	48.9	17.3	51.2	18.2	50.6	18.0	56.5	20.0
39.9	43.3	40.0	15.5	39.7	15.4	49.1	18.9	45.1	17.4	42.4	15.9	43.7	16.9
41.5	43.0	30.1	11.7	37.6	14.6	55.0	21.4	36.0	14.5	44.2	17.3	55.0	21.5
43.4	44.0	28.3	10.7	34.1	12.8	51.9	19.6	42.6	16.1	44.8	16.8	63.5	24.0
45.9	48.6	35.2	12.1	38.7	13.3	55.0	18.9	45.9	15.7	51.8	17.8	64.8	22.2
46.4	44.7	33.6	12.6	40.5	15.2	59.7	21.9	33.1	12.3	42.4	15.8	59.0	22.2
50.6	50.5	46.4	15.3	41.6	13.8	50.7	16.7	55.8	18.4	51.5	17.0	57.0	18.8
51.1	41.9	36.8	14.6	41.1	16.4	55.2	22.0	36.0	14.3	31.5	12.5	51.0	20.2
51.5	46.3	26.4	9.5	44.3	15.9	67.5	24.4	32.6	11.7	42.7	15.4	64.3	23.1



STEEL BRACING IN PLACE

Locomotive Speed-MPH	Recorded Avg Load per Pile Kips	Pile 1 Load in Kips	Pile 1 Percent of Total Load	Pile 2 Load in Kips	Pile 2 Percent of Total Load	Pile 3 Load in Kips	Pile 3 Percent of Total Load	Pile 4 Load in Kips	Pile 4 Percent of Total Load	Pile 5 Load in Kips	Pile 5 Percent of Total Load	Pile 6 Load in Kips	Pile 6 Percent of Total Load
COL 1	2	3	4	5	6	7	8	9	10	11	12	13	14
STATIC	43.2	40.0	15.4	37.1	14.3	44.1	17.0	47.2	18.2	44.1	17.0	46.4	17.9
4.6	46.1	42.4	15.3	40.0	14.5	48.0	17.3	47.0	17.0	46.7	16.9	52.5	19.0
5.1	43.0	41.6	16.1	35.7	13.8	43.5	16.9	48.0	18.6	42.9	16.6	46.4	[illegible]
5.1	44.6	38.4	14.4	37.6	14.1	45.4	17.0	50.2	18.8	46.4	17.5	[illegible]	18.4
5.2	46.2	44.2	16.0	40.0	14.4	47.0	17.0	51.0	18.3	47.8	17.3	47.0	17.0
6.2	45.4	47.2	17.4	38.4	[illegible]	47.2	17.4	48.6	17.8	43.8	16.1	[illegible]	[illegible]
6.3	44.9	45.4	16.8	40.0	14.9	47.0	17.4	45.7	17.3	42.9	15.9	[illegible]	17.7
6.4	44.9	43.7	16.2	40.0	14.9	45.6	16.9	49.4	18.4	43.5	[illegible]	47.2	17.5
7.4	43.9	44.3	16.8	40.8	15.5	45.6	17.3	46.4	17.6	39.7	15.0	46.7	[illegible]
20.5	44.9	45.4	16.8	40.0	14.9	47.5	17.7	44.8	16.6	41.6	15.5	49.3	18.5
21.0	46.2	41.6	15.1	37.9	13.7	44.3	16.1	[illegible]	18.7	47.8	17.2	[illegible]	[illegible]
25.7	44.1	40.0	15.1	38.9	14.7	[illegible]	18.0	42.2	15.9	43.8	16.5	50.6	[illegible]
28.3	45.1	37.9	14.0	38.4	14.0	48.0	17.7	48.0	17.8	45.4	17.2	51.3	19.2
38.4	43.4	43.8	16.9	39.2	15.1	48.6	18.7	41.9	16.1	39.7	15.3	47.0	[illegible]
32.2	44.0	40.3	15.3	40.0	15.2	54.5	20.7	40.6	15.4	39.7	15.1	48.6	18.4
36.3	45.1	40.3	14.9	42.2	15.6	55.0	20.3	39.5	14.6	42.2	15.3	51.5	19.0
36.9	44.0	39.5	15.0	41.9	15.9	55.7	21.1	36.6	13.9	39.2	14.8	51.2	19.4
42.5	43.9	33.1	12.6	40.8	15.5	52.3	19.8	[illegible]	12.6	41.9	15.9	62.4	23.6
42.7	40.4	32.5	12.9	29.1	[illegible]	51.8	[illegible]	40.0	15.3	38.9	15.4	50.1	19.9
43.4	44.4	29.9	11.2	38.4	14.4	55.5	20.9	38.9	14.6	47.0	17.7	56.5	21.2
38.2	41.3	37.3	12.6	44.8	15.2	63.3	21.4	37.4	12.8	41.0	15.9	65.3	[illegible]
48.6	46.6	37.6	13.4	35.5	12.7	42.7	15.3	66.2	23.7	48.3	17.3	49.1	17.6
49.4	44.2	31.2	11.8	41.9	15.8	61.7	23.3	28.3	10.6	40.6	15.3	61.2	23.2
53.4	47.1	34.4	12.2	41.9	14.8	64.8	22.9	32.0	11.3	45.9	16.2	63.8	22.6
53.9	49.6	45.1	14.7	42.6	13.9	52.3	17.0	48.0	15.6	51.0	16.6	58.7	22.2
62.3	45.0	37.6	13.9	47.2	17.5	67.2	24.9	25.6	9.5	36.5	13.5	55.8	20.7



SYMBOL ○ STATIC
● AVERAGE OF 6 HIGHEST

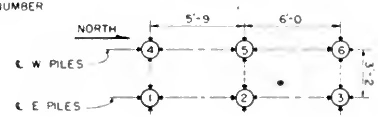
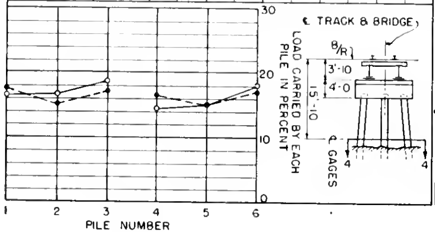


FIG 16
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIER NO 3
LOAD DISTRIBUTION TO PILES
BERKSHIRE TYPE 2-8-4, CLASS "S"

DISTRIBUTION OF LOAD TO INDIVIDUAL PILES OF PIERS 2 & 4 - CALCULATED AVERAGE LOAD PER PILE = 43.4 KIPS

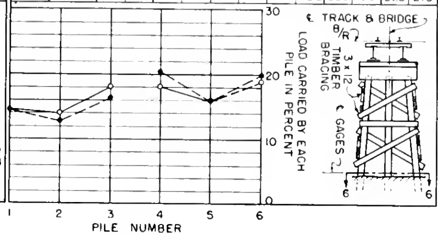
PIER NO 2 - NO BRACING

LOCOMOTIVE SPEED-MPH	RECORDED AVG LOAD PER PILE KIPS	PILE 1 LOAD IN KIPS	PILE 1 PERCENT OF TOTAL LOAD	PILE 2 LOAD IN KIPS	PILE 2 PERCENT OF TOTAL LOAD	PILE 3 LOAD IN KIPS	PILE 3 PERCENT OF TOTAL LOAD	PILE 4 LOAD IN KIPS	PILE 4 PERCENT OF TOTAL LOAD	PILE 5 LOAD IN KIPS	PILE 5 PERCENT OF TOTAL LOAD	PILE 6 LOAD IN KIPS	PILE 6 PERCENT OF TOTAL LOAD
COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14
STATIC	41.4	40.3	16.2	41.6	16.8	46.8	18.9	36.3	14.6	38.1	15.3	45.1	18.2
3.4	43.5	41.4	15.8	43.5	16.6	48.3	18.5	37.9	14.5	41.1	15.8	49.6	19.0
4.5	41.6	40.3	16.3	42.2	17.1	46.2	18.7	35.5	14.3	39.0	15.8	44.3	17.9
4.4	40.8	41.1	16.8	40.8	16.7	47.0	19.2	36.8	15.0	36.0	14.7	43.2	17.6
8.9	42.0	45.1	17.9	42.7	17.0	45.1	17.9	40.0	15.9	36.3	14.4	43.0	17.1
9.4	41.2	38.2	15.5	41.1	16.7	48.0	19.5	35.7	14.5	35.7	14.5	48.2	19.5
18.3	40.0	46.5	19.4	40.0	16.7	39.5	16.5	41.6	17.3	36.0	15.0	36.0	15.0
19.8	42.4	39.5	15.5	42.7	16.8	54.2	21.3	33.6	13.2	36.5	14.3	47.8	18.8
26.0	42.6	43.5	17.0	42.2	16.5	47.8	18.7	41.4	16.2	39.5	15.5	45.9	18.0
26.3	41.7	45.6	18.3	41.1	16.5	43.2	17.3	41.1	16.5	38.4	15.4	40.5	16.2
27.4	44.3	45.1	17.0	44.8	16.9	50.7	19.1	39.7	14.9	39.2	14.7	46.4	17.4
28.8	41.3	40.6	16.4	41.6	16.8	47.3	19.1	37.3	15.0	36.8	14.9	44.0	17.8
32.5	41.5	47.8	19.2	41.9	16.8	42.4	17.0	41.3	16.6	36.8	14.8	38.7	15.5
35.9	43.9	53.1	20.2	45.4	17.3	38.4	14.6	47.8	18.2	40.3	15.3	38.4	14.6
37.8	42.1	49.4	19.5	43.5	17.2	42.4	16.8	43.2	17.1	36.3	14.4	37.9	15.0
39.1	41.3	53.1	21.5	41.6	16.8	32.0	12.9	45.6	18.5	33.9	13.7	41.4	16.7
39.2	45.5	47.0	17.2	42.2	15.5	43.0	15.7	47.0	17.2	45.4	16.6	48.3	17.7
40.4	42.3	48.3	19.1	39.0	15.4	35.5	14.0	50.7	20.0	42.4	16.7	37.6	14.8
42.5	43.5	53.6	20.5	45.1	17.3	40.0	15.3	48.3	18.5	39.0	14.9	35.2	13.5
45.2	48.2	49.6	17.2	45.6	15.8	49.6	17.2	48.0	16.6	45.6	15.8	50.7	17.6
51.0	41.9	52.0	20.7	41.4	16.5	31.8	12.7	50.9	20.2	37.6	15.0	37.9	15.1
51.6	47.7	51.8	18.1	45.4	15.9	47.3	16.5	50.4	17.6	44.3	15.5	47.0	16.4
57.5	49.7	41.1	13.8	45.6	15.3	58.7	19.7	42.4	14.2	47.8	16.1	62.4	20.9



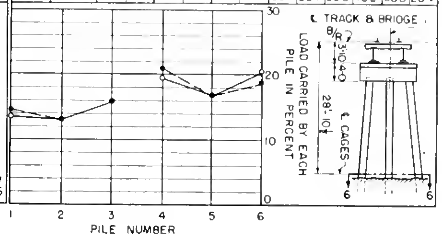
PIER NO 4 - TIMBER BRACING IN PLACE

LOCOMOTIVE SPEED-MPH	RECORDED AVG LOAD PER PILE KIPS	PILE 1 LOAD IN KIPS	PILE 1 PERCENT OF TOTAL LOAD	PILE 2 LOAD IN KIPS	PILE 2 PERCENT OF TOTAL LOAD	PILE 3 LOAD IN KIPS	PILE 3 PERCENT OF TOTAL LOAD	PILE 4 LOAD IN KIPS	PILE 4 PERCENT OF TOTAL LOAD	PILE 5 LOAD IN KIPS	PILE 5 PERCENT OF TOTAL LOAD	PILE 6 LOAD IN KIPS	PILE 6 PERCENT OF TOTAL LOAD
COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14
STATIC	41.3	36.0	14.5	34.7	14.0	44.8	18.1	45.1	18.2	40.3	16.3	47.0	18.9
4.8	43.2	37.4	14.4	35.2	13.6	45.0	17.4	50.2	19.3	41.8	16.1	49.8	19.2
6.0	42.2	36.8	14.5	35.5	14.1	46.4	18.3	45.0	17.8	41.1	16.2	48.3	19.1
6.8	42.7	38.4	15.0	36.8	14.4	47.5	18.5	43.8	17.1	41.6	16.3	47.8	18.7
7.5	43.3	37.6	14.5	35.7	13.8	44.3	17.2	49.8	19.3	43.8	16.4	48.8	18.8
7.6	41.9	39.8	15.8	36.8	14.7	45.8	18.2	47.5	18.9	32.3	12.9	49.1	19.5
19.9	46.1	42.7	15.4	37.6	13.6	46.8	16.9	55.0	19.9	45.8	16.6	48.6	17.6
21.7	43.3	31.0	11.9	33.6	12.9	46.4	17.9	43.5	16.7	45.9	17.7	59.2	22.8
25.6	45.1	31.2	11.5	34.9	12.9	50.2	18.6	45.8	16.9	42.9	15.9	65.6	24.2
27.0	43.9	34.7	13.2	34.1	12.9	46.1	17.5	49.1	18.6	45.4	17.2	54.2	20.6
30.7	42.8	27.8	10.9	34.1	13.3	51.8	20.2	36.8	14.3	43.8	17.1	62.2	24.2
31.1	43.6	31.5	12.0	35.2	13.5	47.8	18.3	43.5	16.7	46.4	17.7	57.1	21.8
35.6	44.7	38.2	14.2	38.4	14.3	49.9	18.6	47.5	17.7	39.5	14.7	54.7	20.4
36.5	43.1	36.3	14.0	36.5	14.1	49.3	19.1	41.3	16.0	42.4	16.4	52.5	20.4
41.3	43.8	39.5	15.0	37.9	14.4	45.0	17.1	52.8	20.1	42.4	16.1	45.4	17.3
41.5	45.6	41.4	15.1	38.7	14.2	43.5	15.9	57.6	21.1	42.6	15.6	49.8	18.1
42.8	46.6	43.0	15.4	40.8	14.6	49.6	17.8	56.8	20.2	42.1	15.0	47.5	17.0
47.5	43.4	37.9	14.6	38.2	14.7	47.5	18.3	46.2	17.8	41.6	16.0	48.8	18.8
47.9	46.3	46.7	16.8	39.7	14.3	42.6	15.4	65.8	23.7	45.4	16.3	37.5	13.5
48.6	45.6	44.5	16.3	39.2	14.3	41.6	15.2	61.6	22.5	42.4	15.5	44.3	16.2
52.7	47.3	40.0	14.1	35.5	12.5	40.8	14.4	63.5	22.4	52.5	18.5	51.5	18.1
58.0	48.2	47.5	16.4	40.5	14.1	42.6	14.8	57.6	19.9	50.4	17.4	50.4	17.4
60.8	45.8	34.4	12.5	32.3	11.8	32.5	11.9	63.8	22.2	53.9	19.6	57.6	21.0

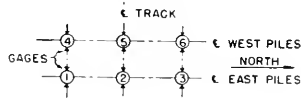


PIER NO. 4 TIMBER BRACING REMOVED

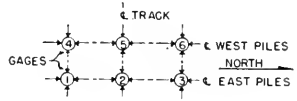
LOCOMOTIVE SPEED-MPH	RECORDED AVG LOAD PER PILE KIPS	PILE 1 LOAD IN KIPS	PILE 1 PERCENT OF TOTAL LOAD	PILE 2 LOAD IN KIPS	PILE 2 PERCENT OF TOTAL LOAD	PILE 3 LOAD IN KIPS	PILE 3 PERCENT OF TOTAL LOAD	PILE 4 LOAD IN KIPS	PILE 4 PERCENT OF TOTAL LOAD	PILE 5 LOAD IN KIPS	PILE 5 PERCENT OF TOTAL LOAD	PILE 6 LOAD IN KIPS	PILE 6 PERCENT OF TOTAL LOAD
COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14
STATIC	40.2	33.1	13.7	31.7	13.1	39.2	16.1	46.9	19.4	41.1	17.0	49.4	20.5
5.0	42.4	36.0	14.2	33.1	13.0	40.8	16.1	49.8	19.6	45.3	17.8	49.3	19.4
5.7	43.1	35.5	13.8	34.9	13.5	43.7	16.9	51.4	19.9	43.7	16.9	49.1	19.0
6.1	42.0	34.1	13.5	33.6	13.3	41.3	16.5	50.7	20.1	43.4	17.2	48.8	19.4
7.5	44.1	36.5	13.8	37.9	14.3	44.0	16.6	45.1	17.0	52.0	19.6	49.1	18.5
7.5	44.8	35.5	13.2	36.0	13.4	45.1	16.8	53.3	19.8	47.2	17.6	51.4	19.1
8.5	46.1	39.2	14.2	38.1	13.8	44.0	15.9	56.0	20.2	47.2	17.1	52.0	18.8
20.8	43.8	38.9	14.8	36.3	13.8	45.1	17.1	52.8	20.1	41.4	15.7	48.3	18.3
21.4	43.2	33.3	12.9	34.4	13.3	45.3	17.5	47.5	18.3	48.0	18.5	50.7	19.6
26.2	45.3	35.5	13.0	36.3	13.3	46.1	17.0	54.7	20.1	46.1	17.0	53.1	19.5
26.3	44.8	34.7	12.9	34.9	13.0	46.1	17.1	49.4	18.4	49.9	18.6	54.1	20.1
29.8	44.6	36.5	13.6	37.1	13.9	47.2	17.6	51.0	19.1	44.8	16.8	51.0	19.1
31.5	44.6	33.3	12.5	35.5	13.3	47.7	17.8	47.5	17.8	52.3	19.6	51.4	19.2
35.8	42.1	33.3	13.2	35.2	13.9	44.8	17.7	47.0	18.6	44.8	17.7	47.7	18.6
37.6	48.4	37.3	12.9	38.7	13.3	44.8	15.4	59.5	20.5	54.2	18.7	55.8	19.2
39.0	45.0	42.4	15.7	39.2	14.5	47.2	17.5	53.9	19.9	40.3	14.9	47.0	17.4
43.4	49.0	44.6	15.2	39.2	13.3	44.5	15.1	62.7	21.3	48.0	16.3	55.0	18.7
44.0	49.4	41.4	14.0	37.6	12.7	43.4	14.7	64.3	21.7	51.2	17.3	58.5	19.7
48.5	45.7	41.6	15.2	37.3	13.6	40.3	14.7	57.4	20.9	46.4	16.9	51.2	18.7
49.5	50.7	48.0	15.8	41.4	13.6	45.6	15.0	61.4	20.2	51.0	16.8	56.6	18.6
50.0	43.6	33.1	12.7	37.9	14.5	49.8	19.1	48.9	18.7	44.6	17.1	47.2	18.1
53.0	48.9	43.5	14.9	41.1	14.0	50.1	17.1	61.1	20.9	46.4	15.8	51.2	17.5
54.5	51.3	44.2	14.3	42.7	13.8	51.4	16.7	63.8	20.7	49.9	16.2	55.8	18.1
61.5	49.0	35.7	12.1	34.4	11.7	43.4	14.7	66.7	22.7	53.6	18.2	60.0	20.4



SYMBOL: ○ STATIC
● AVERAGE OF 6 HIGHEST



SECTION 4-4



SECTION 6-6

FIG 17
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIERS 2 & 4

LOAD DISTRIBUTION TO PILES

BERKSHIRE TYPE 2-8-4, CLASS "S"

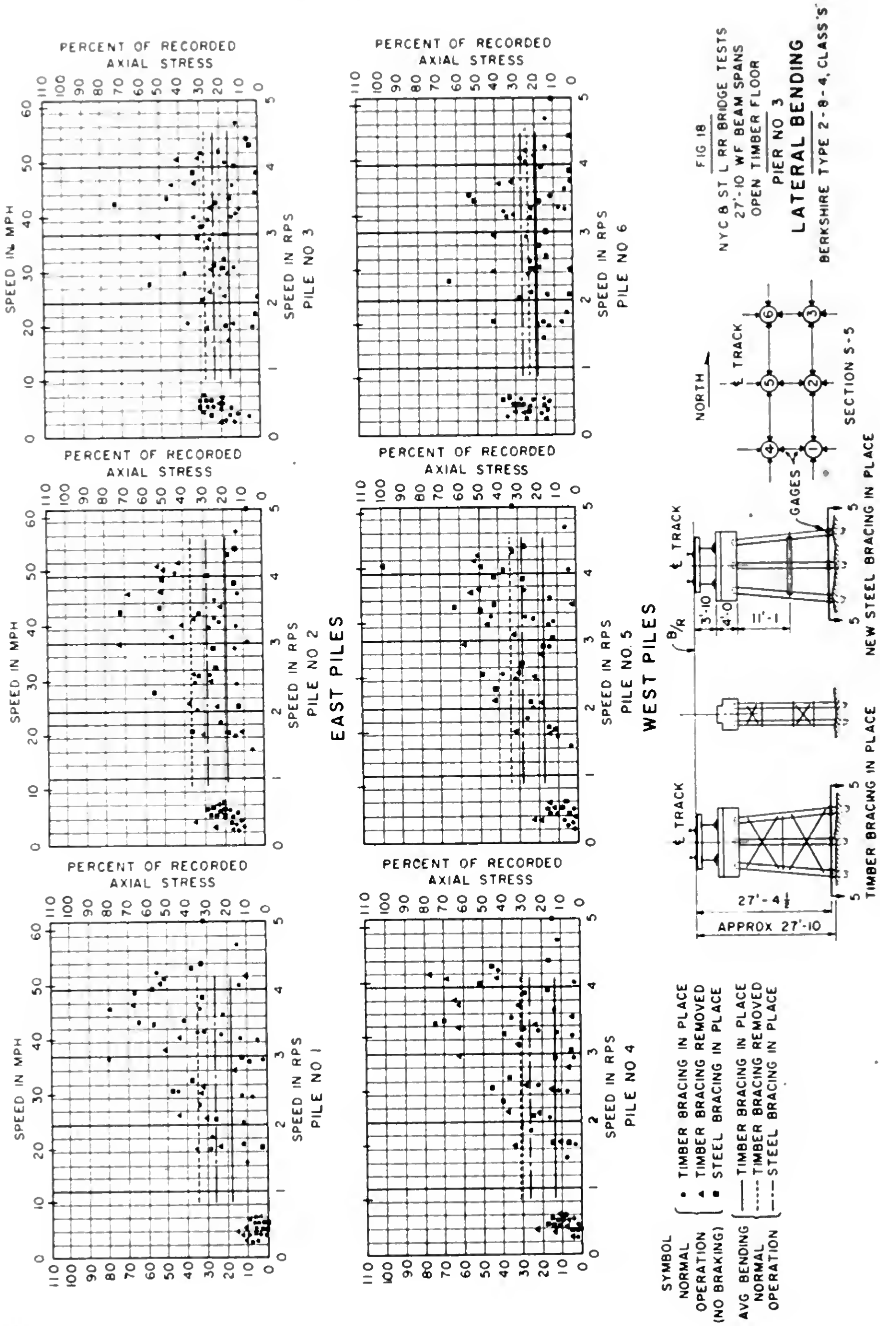


FIG 18
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIER NO 3
LATERAL BENDING
BERKSHIRE TYPE 2-8-4, CLASS 'S'
EAST PILES
WEST PILES
PILE NO 1
PILE NO 2
PILE NO 3
PILE NO 4
PILE NO 5
PILE NO 6
PERCENT OF RECORDED AXIAL STRESS
SPEED IN MPH
SPEED IN RPS
NORTH
℄ TRACK
GAGES
SECTION 5-5
NEW STEEL BRACING IN PLACE
TIMBER BRACING IN PLACE
APPROX 27'-10
27'-4½
3'-10
4'-0
11'-1
B/R
SYMBOL
NORMAL OPERATION (NO BRAKING)
• TIMBER BRACING IN PLACE
▲ TIMBER BRACING REMOVED
■ STEEL BRACING IN PLACE
AVG BENDING NORMAL OPERATION
—— TIMBER BRACING IN PLACE
----- TIMBER BRACING REMOVED
-·-·- STEEL BRACING IN PLACE

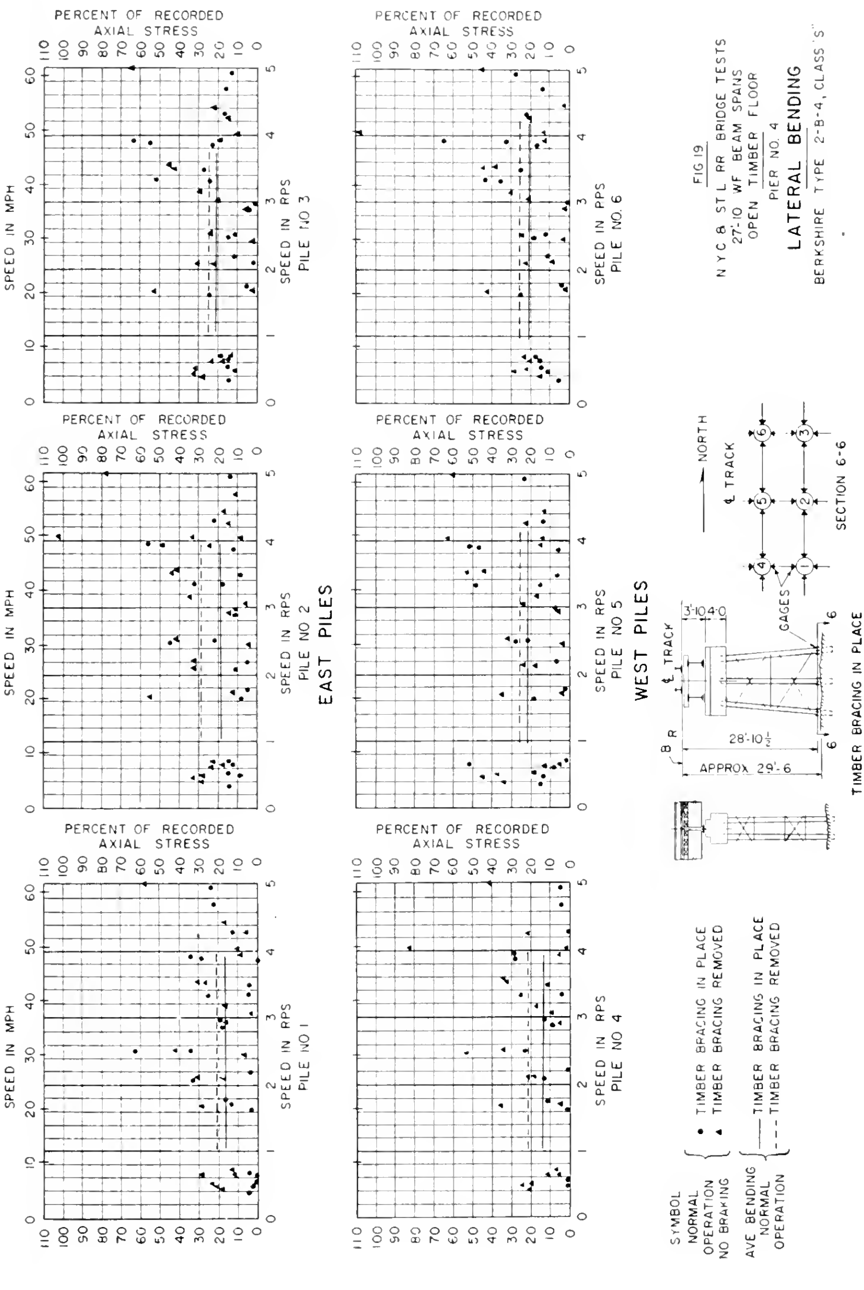


FIG 19
N Y C & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIER NO. 4
LATERAL BENDING
BERKSHIRE TYPE 2-B-4, CLASS 'S'

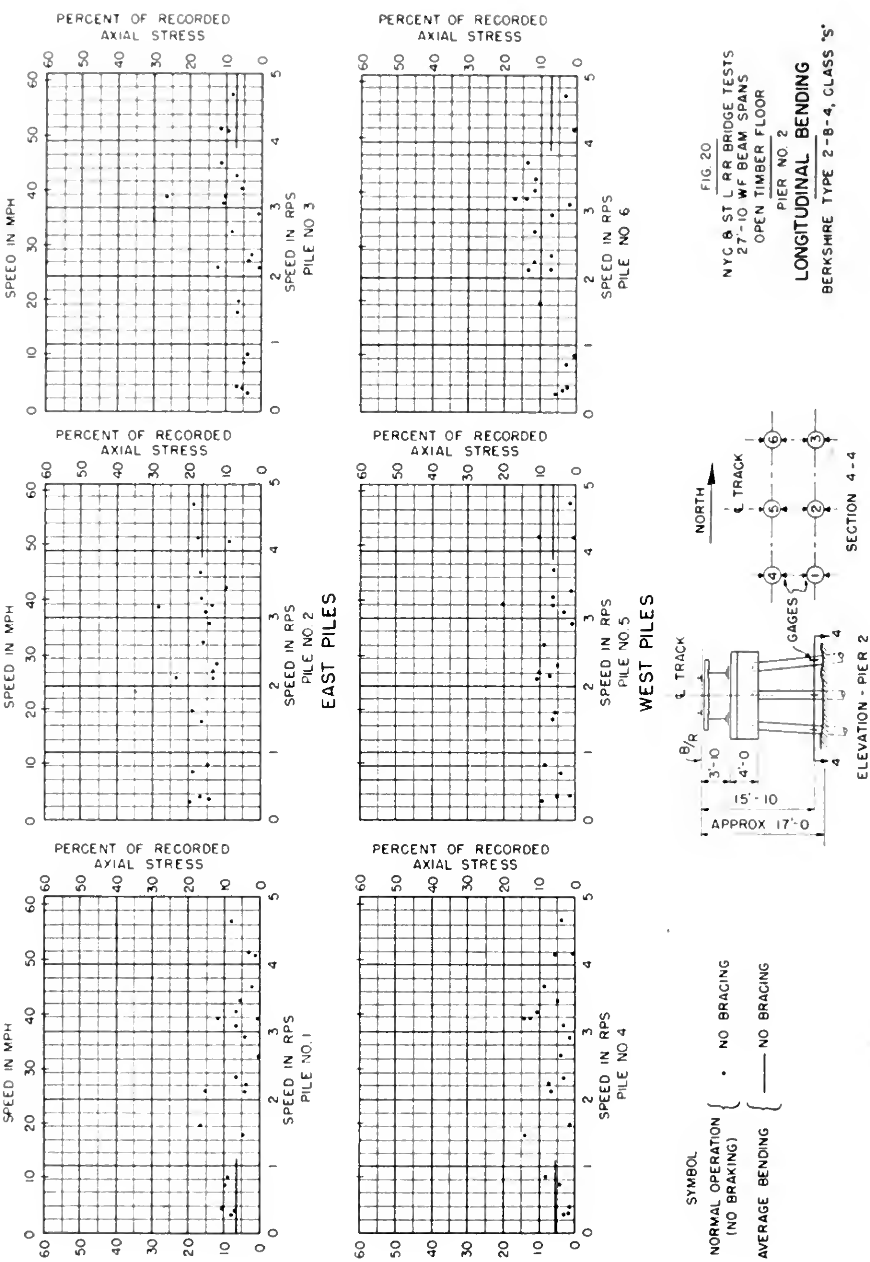


FIG. 20
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIER NO. 2
LONGITUDINAL BENDING
BERKSHIRE TYPE 2-8-4, CLASS "S"

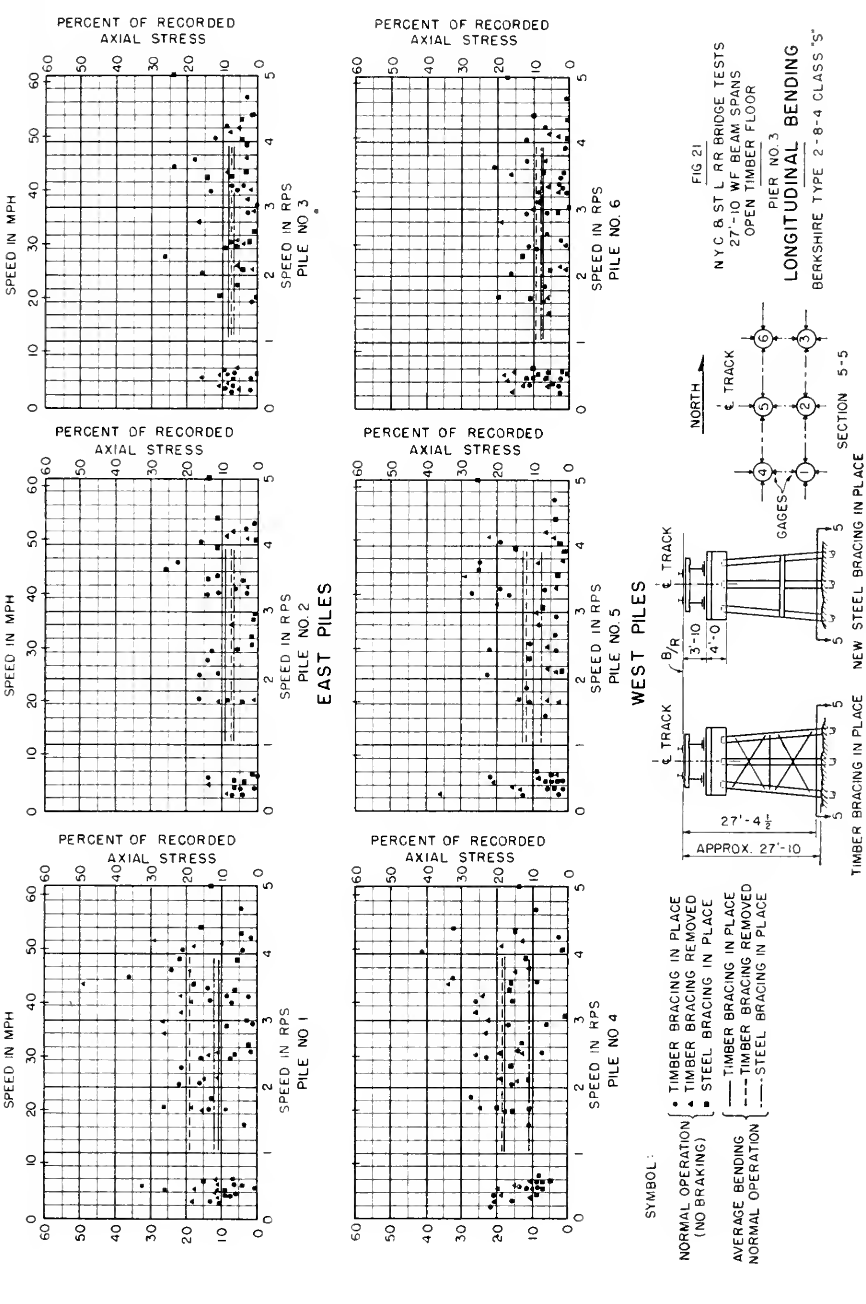


FIG 21
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIER NO. 3
LONGITUDINAL BENDING
BERKSHIRE TYPE 2-8-4 CLASS "S"

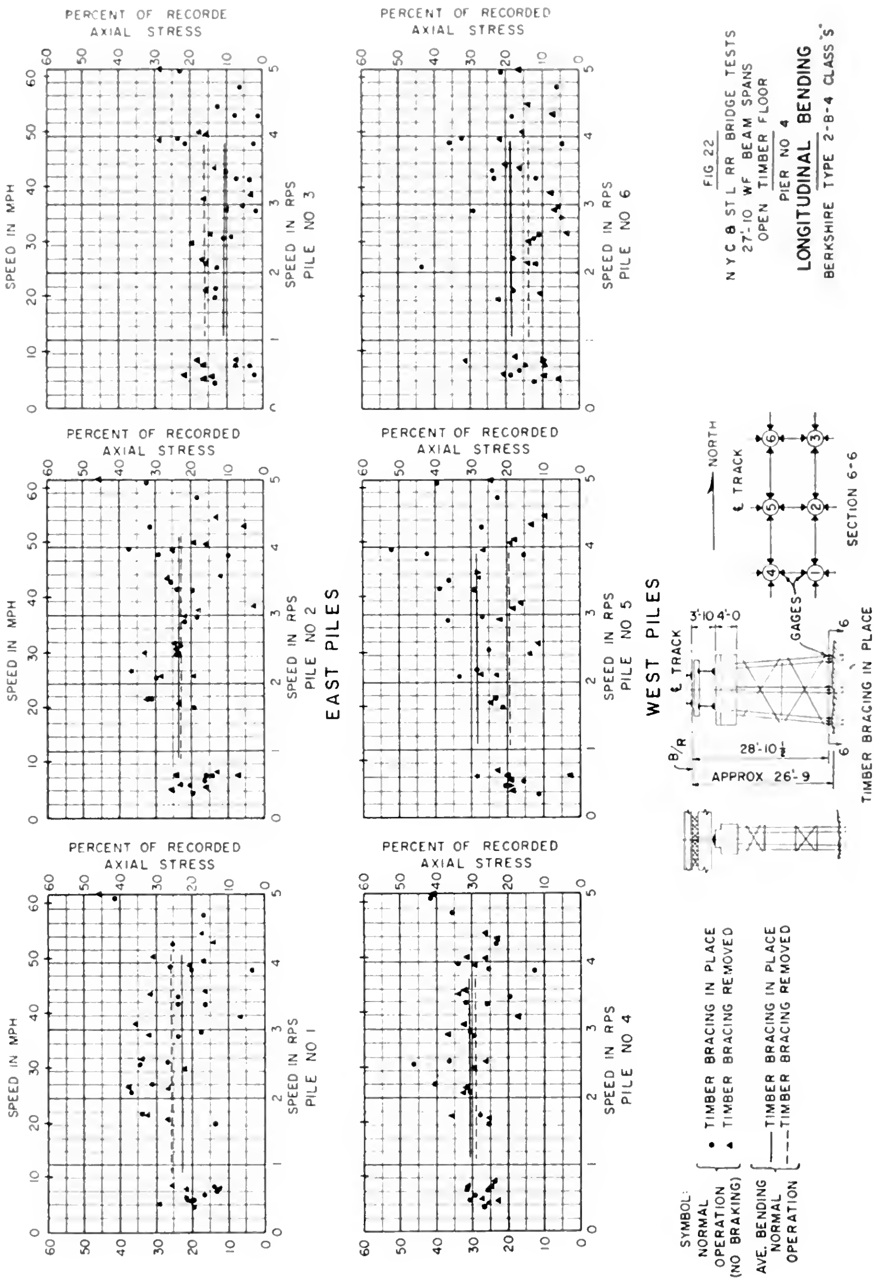
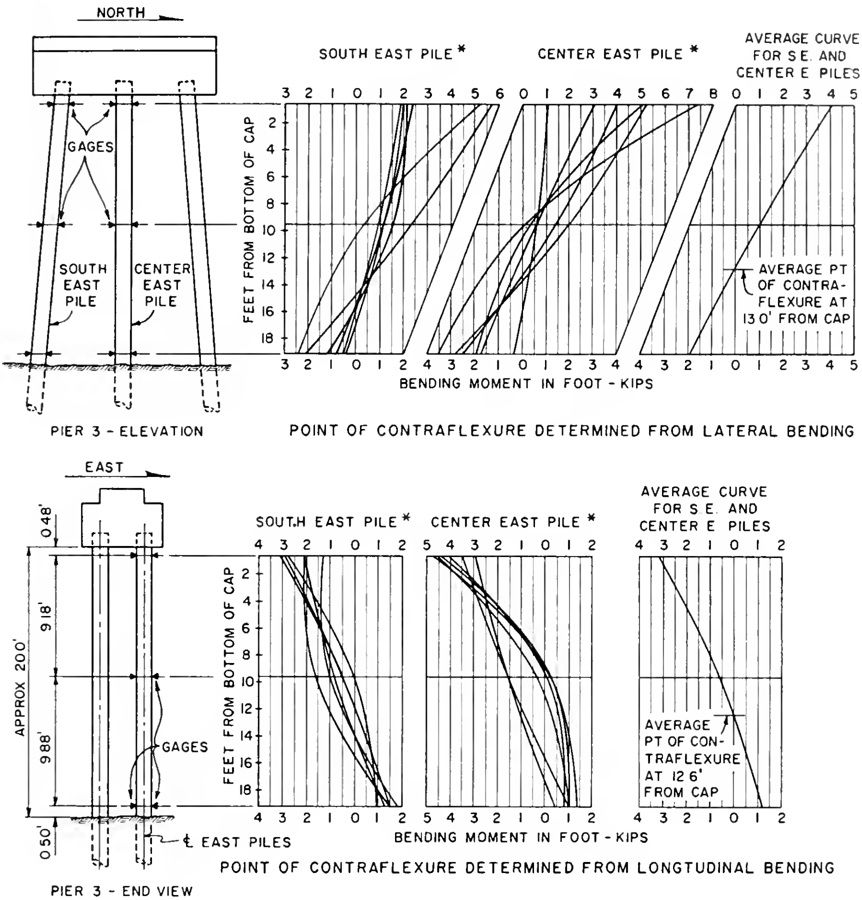
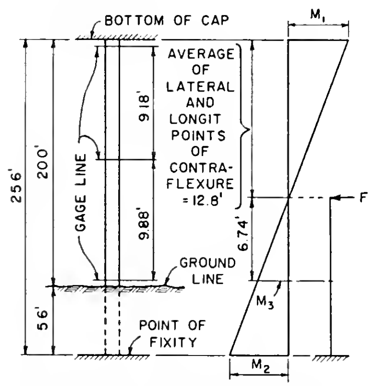


FIG 22
N Y C & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIER NO 4
LONGITUDINAL BENDING
BERKSHIRE TYPE 2-8-4 CLASS 'S'





METHOD OF DETERMINING LATERAL AND LONGITUDINAL FORCE ON PIER 3

NOTES. * CURVES SHOWN ARE FOR TRAIN SPEEDS VARYING FROM 5 TO 58 MPH

M_1 = BENDING MOMENT IN PILE AT BOTTOM OF CAP (PILE FIXED AT THIS POINT)

M_2 = BENDING MOMENT IN PILE AT POINT OF FIXITY IN GROUND $M_1 = M_2$

M_3 = BENDING MOMENT CALCULATED FROM LATERAL OR LONGITUDINAL SR-4 GAGES

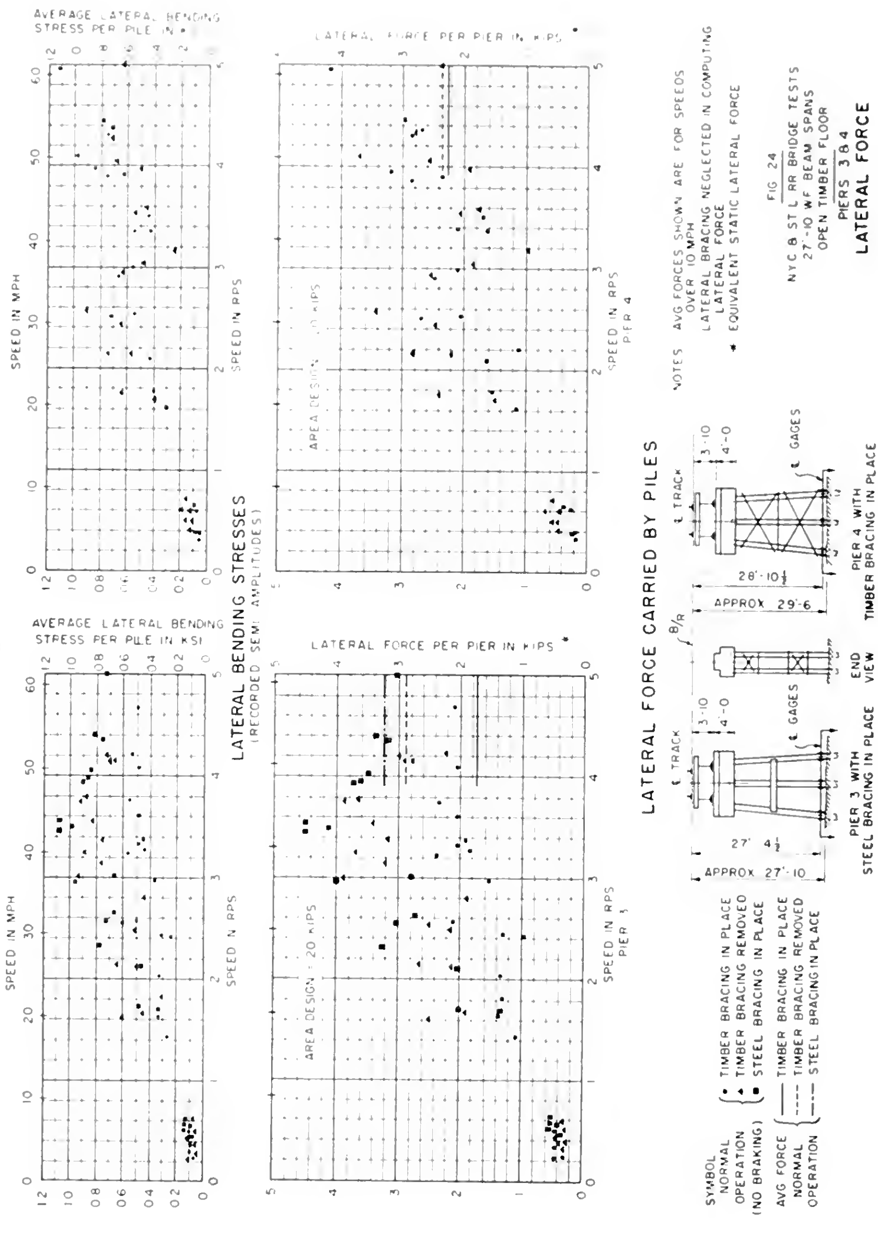
F = LATERAL OR LONGITUDINAL FORCE APPLIED AT PT OF CONTRAFLEXURE TO CAUSE MOMENT M_3

FIG. 23

NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR

PIER NO 3

DETERMINATION OF LATERAL AND LONGITUDINAL FORCES FROM POINT OF CONTRAFLEXURE IN PILES


LATERAL BENDING STRESSES
(RECORDED SEMI AMPLITUDES)
AVERAGE LATERAL BENDING STRESS PER PILE IN KSI
SPEED IN MPH
SPEED IN RPS
LATERAL FORCE PER PIER IN KIPS *
AREA DESIGN = 20 KIPS
SPEED IN RPS PIER 3
SPEED IN RPS PIER 4
LATERAL FORCE CARRIED BY PILES
℄ TRACK
GAGES
3'-10
4'-0
27' 4½
APPROX 27'-10
PIER 3 WITH STEEL BRACING IN PLACE
END VIEW
28'-10½
APPROX 29'-6
PIER 4 WITH TIMBER BRACING IN PLACE
SYMBOL NORMAL OPERATION (NO BRAKING)
TIMBER BRACING IN PLACE
TIMBER BRACING REMOVED
STEEL BRACING IN PLACE
AVG FORCE NORMAL OPERATION
TIMBER BRACING IN PLACE
TIMBER BRACING REMOVED
STEEL BRACING IN PLACE
NOTES AVG FORCES SHOWN ARE FOR SPEEDS OVER 10 MPH
LATERAL BRACING NEGLECTED IN COMPUTING LATERAL FORCE
* EQUIVALENT STATIC LATERAL FORCE
FIG 24
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIERS 3 & 4
LATERAL FORCE

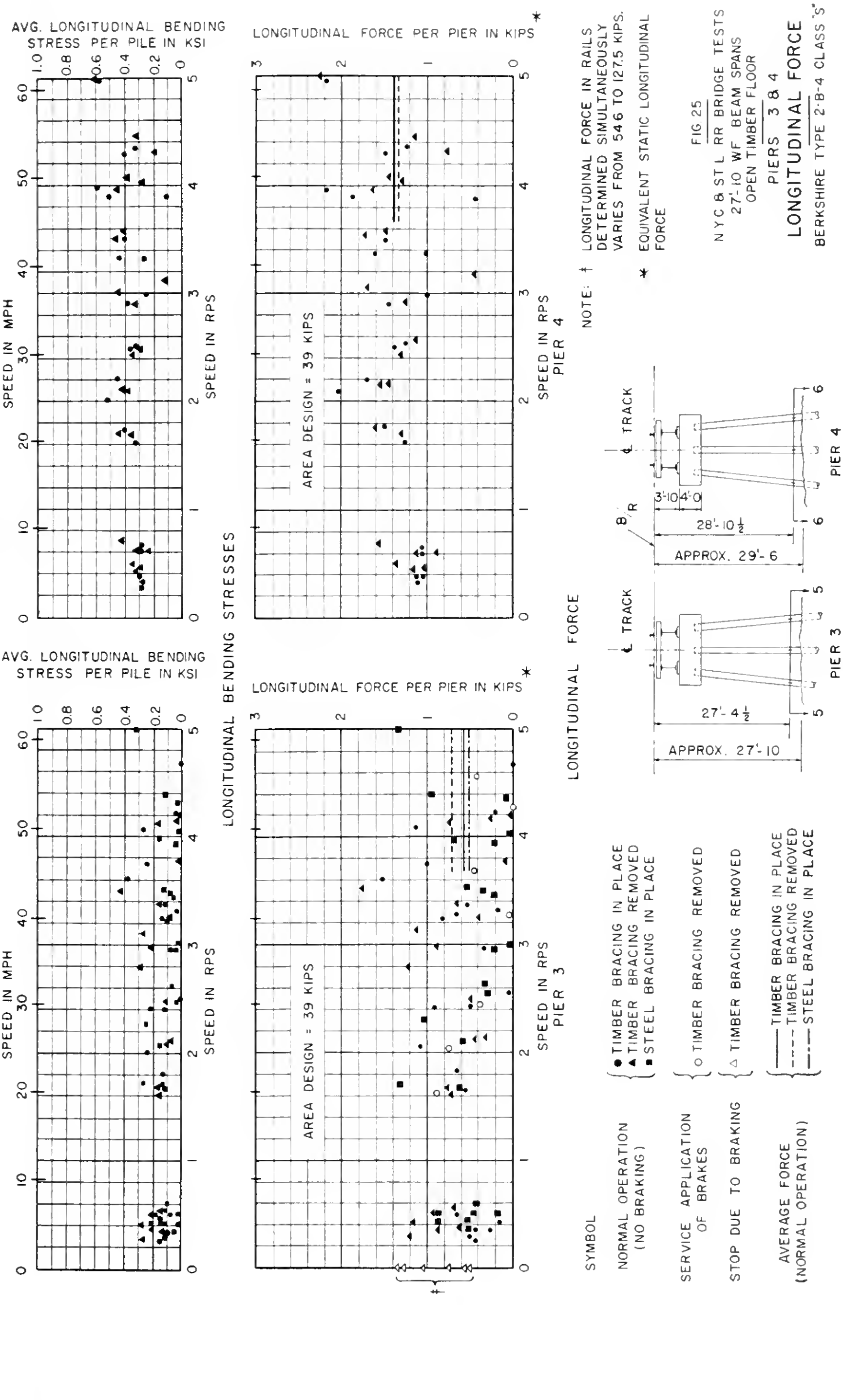


FIG. 25
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIERS 3 & 4
LONGITUDINAL FORCE
BERKSHIRE TYPE 2-B-4 CLASS 'S'

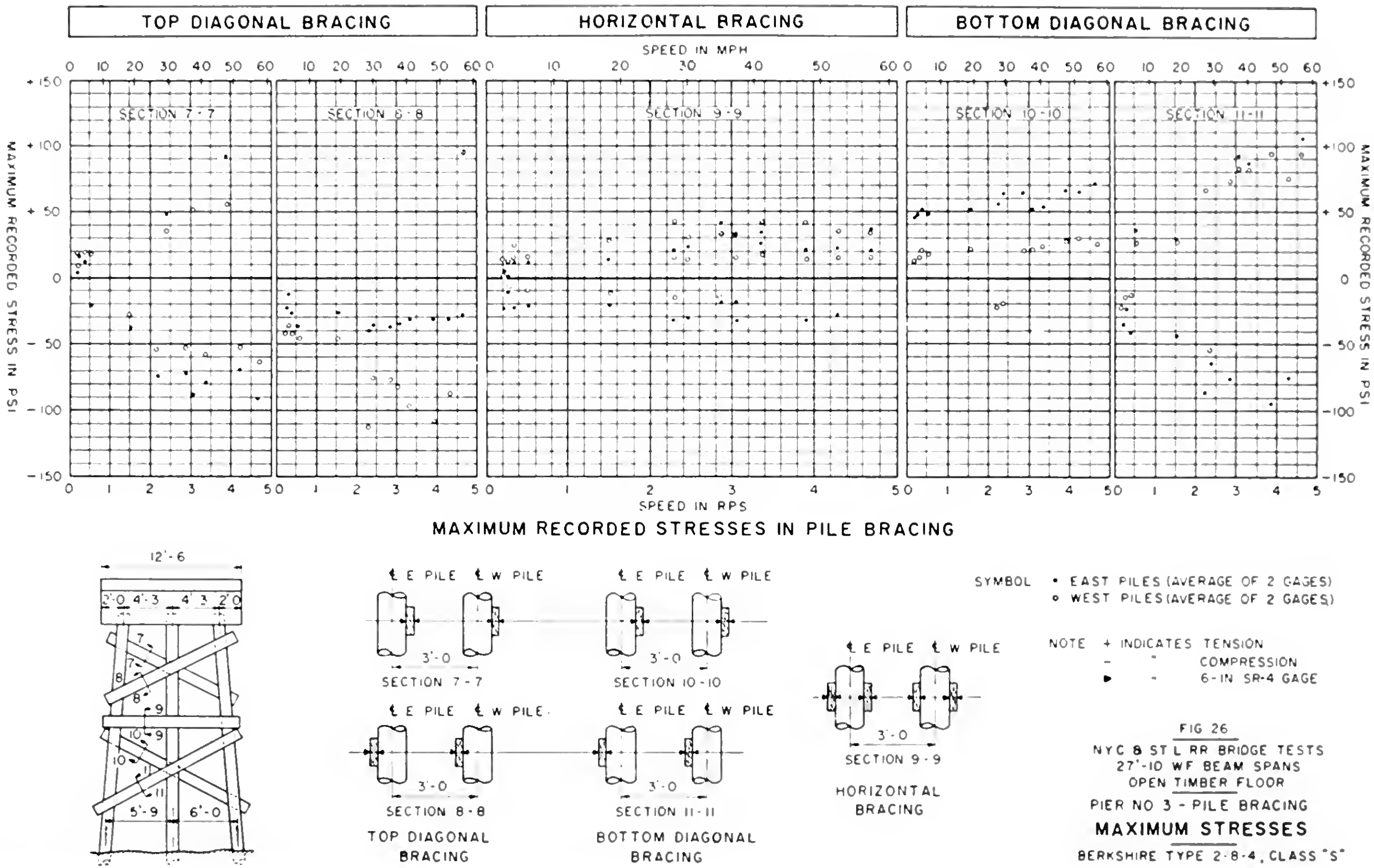
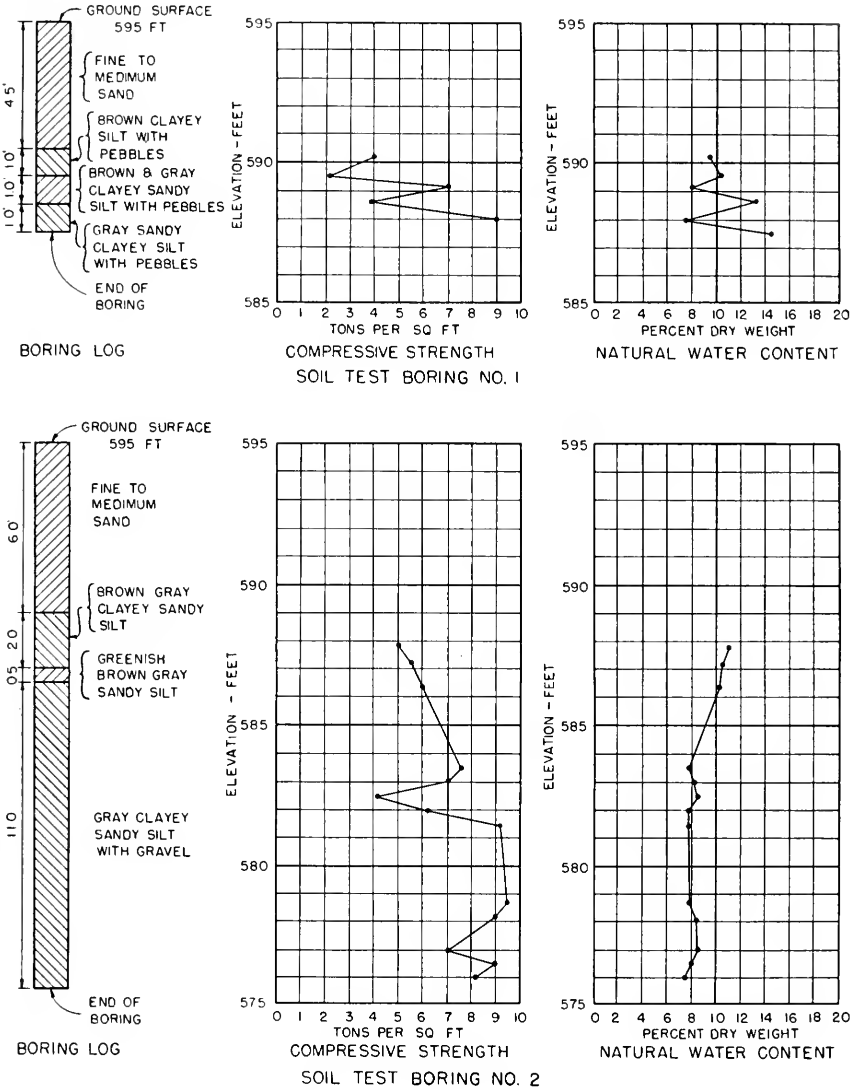


FIG 26
NYC & ST L RR BRIDGE TESTS
27'-10 WF BEAM SPANS
OPEN TIMBER FLOOR
PIER NO 3 - PILE BRACING
MAXIMUM STRESSES
BERKSHIRE TYPE 2-8-4, CLASS "S"



NOTE FOR LOCATION OF BORINGS
SEE FIG. 5 (PLAN VIEW)

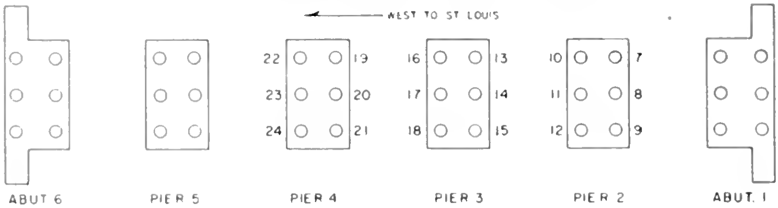
FIG. 27
NYC & ST L BRIDGE TESTS
28 WF BEAM SPANS
OPEN TIMBER FLOOR
SOIL TEST BORINGS

FIG 28

NYC & ST L RR BRIDGE TESTS

27'-10 WF BEAM SPANS - OPEN TIMBER FLOOR

PILE DRIVING RECORD – PIERS 2, 3 & 4



PIER 2			
PILE NO	PENETRATION	NO BLOWS LAST FOOT	DATE DRIVEN
7	29.2	56	7-6-50
8	29.0	34	
	30.0	43	9-20-50
	31.0	45	
	32.0	45	
	33.0	46	
	34.0	51	
	35.0	48	
	36.0	49	
	36583	28	
9	30.0	30	7-11-50
	31.0	31	9-20-50
	32.0	43	
	34.0	45	
	35.0	40	
	36.0	36	
	37.0	40	
	38.0	40	
10	29.0	45	7-6-50
11	28.0	45	
12	18.0	14	7-11-50
	23.0	24	
	26.0	27	
	28.0	28	
	30.0	32	
	32.0	41	9-20-50
	33.0	37	
	34.0	45	
	35.0	45	
	36.0	38	
	37.0	38	
	38.0	37	

PIER 3			
PILE NO	PENETRATION	NO BLOWS LAST FOOT	DATE DRIVEN
13	21.0	58	7-6-50
	23.5	64	
14	23.6	56	
	25.5	66	
15	20.0	39	7-11-50
	22.0	47	
	24.0	62	
16	20.0	60	7-6-50
	22.5	72	
17	22.0	60	
	23.5	76	
18	18.0	38	7-11-50
	21.0	48	
	23.5	56	
	25.0	60	

PIER 4			
PILE NO	PENETRATION	NO BLOWS LAST FOOT	DATE DRIVEN
19	18.7	60	7-6-50
	19.9	80	
20	17.0	60	7-5-50
	19.0	80	
	20.5	104	
21	23.0	60	7-11-50
	24.0	70	
22	17.0	65	7-5-50
	20.5	100	
23	18.5	60	
	20.5	150	
24	21.0	48	7-11-50
	23.2	54	

NOTES

LENGTH OF PILES ORDERED AND IN LEADS = 40 FT

40 FT PILES WERE EXTENDED BY SPLICING BEFORE BEING DRIVEN TO TABULATED PENETRATION

PILES WERE DRIVEN BY NYC & ST L FORCES

MAKE, TYPE & NO OF HAMMER – NO I VULCAN (S.A.)

WEIGHT OF HAMMER = 5000 LB

MEASURED STROKE = 3 FT

TYPE OF PILE - ARMCO STEEL PIPE PILE

TABLE 1

N.Y.C. & ST.L. RR. BRIDGE TESTS

27'-10 WF BEAM SPANS - OPEN TIMBER FLOOR

COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES IN BEAMS

TYPE OF STRESS	TEST LOCOMOTIVE	SPAN	RECORDED STRESS NORTH BEAM	RECORDED STRESS SOUTH BEAM	RECORDED STRESS AVERAGE	AVERAGE CALCULATED STATIC STRESS	STRESS FACTOR = RECORDED / CALCULATED	
COL. 1	2	3	4	5	6	7	8	9
BENDING MOMENT AT CENTER OF BEAM	BERKSHIRE TYPE 2-8-4 CLASS "S" NUMBER 700	NO. 1	5.50	5.80	5.65	7.08	0.80	0.76
			5.20	5.50	5.35		0.75	
			4.90	5.30	5.10		0.72	
			5.10	6.00	5.55		0.78	
			5.10	5.50	5.30		0.75	
		NO. 2	5.50	6.10	5.80	7.08	0.82	0.80
			6.10	5.70	5.90		0.83	
			6.00	5.40	5.70		0.80	
			5.70	4.70	5.20		0.73	
			5.90	5.70	5.80		0.82	
		NO. 3	5.80	5.80	5.80	7.08	0.82	0.80
			5.70	5.90	5.80		0.82	
			5.70	5.70	5.70		0.80	
			5.80	5.10	5.45		0.77	
			5.70	5.30	5.50		0.78	

NOTE: STRESSES IN BEAMS ARE TENSILE AND GIVEN IN KSI.

TABLE 2

N.Y.C. & ST.L. RR. BRIDGE TESTS

27'-10 WF BEAM SPANS - OPEN TIMBER FLOOR

COMPARISON OF RECORDED AND CALCULATED DIRECT STATIC STRESSES IN PILES

TYPE OF STRESS	TEST LOCOMOTIVE	PIER NO.	CALCULATED AVERAGE STATIC STRESS	EAST PILES									WEST PILES									AVER S.F. PER PIER
				NORTH PILE			CENTER PILE			SOUTH PILE			NORTH PILE			CENTER PILE			SOUTH PILE			
				RECORDED	STRESS FACTOR	AVER	RECORDED	STRESS FACTOR	AVER	RECORDED	STRESS FACTOR	AVER	RECORDED	STRESS FACTOR	AVER	RECORDED	STRESS FACTOR	AVER	RECORDED	STRESS FACTOR	AVER	
COL. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AVERAGE DIRECT STRESS IN PILES NEAR GROUND LINE.	BERKSHIRE TYPE 2-8-4 NO. 700 - CLASS "S"			1.79	1.10		1.60	0.98		1.53	0.94		1.84	1.13		1.52	0.93		1.40	0.86		
				1.71	1.05		1.56	0.96		1.49	0.91		1.64	1.01		1.44	0.88		1.31	0.80		
		2	1.63	1.74	1.07	1.09	1.51	0.93	0.96	1.52	0.93	0.94	1.60	0.98	1.04	1.33	0.82	0.86	1.36	0.83	0.85	0.96
				1.68	1.03		1.60	0.98		1.68	1.03		1.56	0.96		1.36	0.83		1.50	0.92		
				1.80	1.10		1.53	0.94		1.43	0.88		1.81	1.11		1.33	0.82		1.33	0.82		
				1.62	0.99		1.37	0.84		1.51	0.93		1.54	0.94		1.61	0.99		1.48	0.91		
				1.76	1.08		1.41	0.87		1.58	0.97		1.57	0.96		1.40	0.86		1.60	0.98		
		3	1.63	1.50	0.92	1.01	1.36	0.83	0.85	1.46	0.90	0.92	1.54	0.94	0.96	1.54	0.94	0.92	1.62	0.99	0.97	0.94
				1.58	0.97		1.26	0.76		1.33	0.82		1.73	1.06		1.52	0.93		1.71	1.05		
				1.79	1.10		1.52	0.93		1.60	0.98		1.43	0.88		1.40	0.86		1.49	0.91		
				1.43	0.88		1.17	0.72		1.27	0.78		1.87	1.15		1.60	0.98		1.77	1.08		
				1.55	0.95		1.23	0.75		1.26	0.76		1.84	1.13		1.54	0.94		1.81	1.11		
		4	1.63	1.43	0.88	0.92	1.17	0.72	0.75	1.19	0.73	0.75	1.83	1.12	1.13	1.49	0.91	1.00	1.71	1.05	1.07	0.94
				1.57	0.96		1.23	0.75		1.21	0.74		1.94	1.19		1.67	1.02		1.89	1.16		
				1.54	0.93		1.32	0.81		1.26	0.76		1.70	1.04		1.89	1.16		1.53	0.94		

NOTES: STRESSES IN PILES ARE COMPRESSIVE AND GIVEN IN KSI.
STRESS FACTOR AS GIVEN IS THE RATIO OF RECORDED TO CALCULATED STRESS.
RECORDED VALUES ARE AVERAGE OF 4 GAGES FOR PILES IN PIERS 3 AND 4,
AND AVERAGE OF 2 GAGES FOR PILES IN PIER 2.

Advance Report of Committee 30—Impact and Bridge Stresses

Description and Analysis of Tests Made on Transverse Floorbeams and Longitudinal Beams Under Diesel and Steam Locomotives

A. DIGEST

This report includes a description and analysis of tests made on seven through girder spans having transverse floorbeams without stringers (see Figs. 1 and 3), and two spans having closely spaced longitudinal beams (see Fig. 2). Both of these types provide the shallow floor required for a limited depth from base of rail to the under-clearance line. Some of the varying features of the bridges are as follows:

1. Single and double-track structures.
2. Ties set either on concrete-lined floor plate or on timber stringers bearing on floor plate.
3. Ballasted track on floor plate, on concrete-lined floor plate, and on reinforced concrete slabs.
4. Transverse floorbeams with diaphragms connected and later disconnected.
5. Longitudinal beams not encased and later encased in concrete.
6. Transverse floorbeams at 4-ft 9-in centers with shallow stringers.

The tests were made under diesel and steam locomotives of regular trains operating at normal speeds with some speed restrictions requested to obtain data under static conditions. Data were secured under 127 steam locomotives at speeds ranging from 3 to 84 mph and under 99 diesel locomotives ranging in speeds from 4 to 85.4 mph. The purpose of these tests was to determine the distribution of locomotive axle loads and the variation in stresses on the closely spaced transverse and longitudinal beams. The data were further analyzed for the impact effects in transverse floorbeams.

The stresses were measured by means of wire resistance strain gages with oscillograph recordings. On transverse floorbeams, whose spans varied from 11 ft 3 in to 19 ft 3 in for single track and from 30 ft 6 into 31 ft 8 in for double-track bridges, and whose floor-beam spacing varied from 1 ft $4\frac{5}{16}$ in to 2 ft $10\frac{3}{8}$ in, the maximum and simultaneous stresses were measured in 24 consecutive beams with the gages located on the bottom flanges at the center line of track. On longitudinal beams, whose spacing varied from $10\frac{1}{2}$ in to 2 ft $0\frac{15}{16}$ in, and whose spans varied from 22 ft 5 in to 45 ft, the maximum and simultaneous stresses were measured in 12 to 24 beams on the bottom flanges at the center line of span.

A brief summary of the test data is as follows:

1. The recorded average maximum static stresses are compared with the calculated static stresses in Cols. 7 and 8 of Table 3, which indicates that the recorded stresses are lower than the calculated. The greatest differences were found for the New York Central Railroad bridge (39 ft $0\frac{1}{4}$ in), and the Baltimore & Ohio Railroad bridge (74 ft $7\frac{5}{8}$ in). On these two bridges the calculated stresses were 2 to $2\frac{1}{2}$ times larger than the recorded stresses for locomotive types 4–6–4 and 4–8–2 which were used on these two bridges. This difference can be partially explained by a better transverse distribution of axle loads through the deep ballast and concrete-lined floor plate for the NYC bridge and the reinforced concrete slab on the B&O bridge, and interaction of the concrete liner or slab with the steel beams.

2. The tests conducted on the NYC 70-ft span afforded an opportunity to study the effects of diaphragms in helping distribute the axle loads. The maximum stresses shown by the open circles on Fig. 11 were recorded with the diaphragms connected. Those shown by the solid circles were recorded after the rivets connecting the diaphragm to the beams had been removed. It can be seen that the average maximum stress was increased from 3.12 to 3.35 ksi after the diaphragms were disconnected.

3. A comparison of recorded and calculated simultaneous stresses in the floorbeams of the Southern Railway bridge under steam and diesel locomotives is shown on the lower diagrams of Fig. 10. The vertical pressures from the axle loads on the beams are shown in the center diagram. The calculated stresses were based on a method developed by Dr. A. N. Talbot for the determination of rail stresses, and it can be seen that the recorded and calculated stresses are in close agreement.

4. The distribution factor "K" as recommended by the AREA specifications is compared with "K_E", an experimental distribution factor found from these tests. Reference to Table 3 shows that "K_E" approaches "K" for the NYC 70-ft span (track 3), the Chicago, Burlington & Quincy Railroad 100-ft span, and the NYC 93-ft 5-in span. In the NYC bridges the tracks are not ballasted, and the axle loads are directly transferred to the floorbeams. In the CB&Q bridge the depth of ballast is only 5 in, thus bringing the axle loads close to the floorbeams. The results obtained on the Southern 58-ft 4½-in span with its 11-in depth of ballast and average "K_E" of 0.88 also can be pointed out in support of the fact that the depth of ballast affects the distribution factor. A concrete lining on the floor plate or a concrete slab on top of the floorbeams affect the distribution factor and also introduce composite action of steel and concrete.

5. As a locomotive passes over a span, the stresses in each of the 24 floorbeams tested should be the same, but it can be seen from the diagrams of maximum stresses, Figs. 5, 11, 14, 19, 25 and 29, that considerable variation in stress was found in the various beams. The greatest variation occurred in floorbeam 1 where the maximum recorded stress was 57 percent greater than the average recorded maximum stress of all 24 floorbeams (see Fig. 20, run 14).

6. It can be seen from Figs. 5, 11, 19, 25, 29, 33 and 35 that the stress distribution pattern in the floorbeams is similar at high speeds and at slow speeds.

7. The maximum stresses recorded in any of the transverse floorbeams under locomotives passing over the spans at high speeds were considerably lower than the calculated stresses using the AREA design specifications for distribution and impact. For example, the maximum stress on the Southern span was measured in floorbeam 10 (see Fig. 7, run 13). This measured stress of 7 ksi was 73 percent of the calculated stress of 9.56 ksi based on the section modulus of the floorbeam only.

8. Total impacts expressed in percent of recorded static stresses were determined for the transverse floorbeams in each of the six bridges tested, and the results as well as the AREA design impact allowances for diesel and steam locomotives are shown on Fig. 42. The recorded impacts for the NYC 39-ft span exceeded the allowable values for both diesel and steam locomotives. The concrete floor-plate lining and the 2-ft depth of ballast on this bridge helped in the distribution of axle loads, thus reducing the recorded static stresses to low values, which resulted in high impact percentages. It can be noted that the lowest values of impact were recorded in the floorbeams of the double-track bridges, since the impact effect was distributed over a larger area, thus having a larger damping effect.

9. The test results on the longitudinal beams of two bridges are shown in Figs. 43 to 52, incl., for the NYC bridge, and in Figs. 53 to 60, incl., for the Missouri–Kansas–

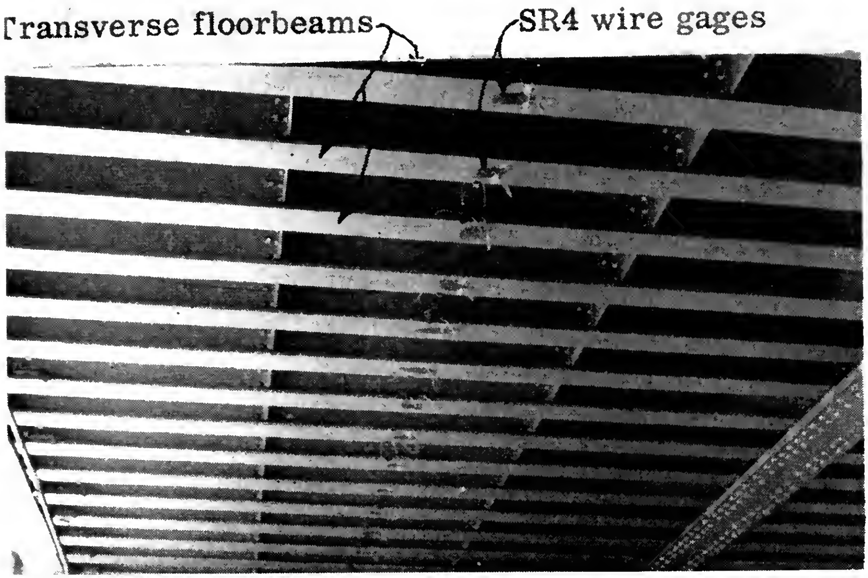


Fig. 1—General view of gages on transverse floorbeams.

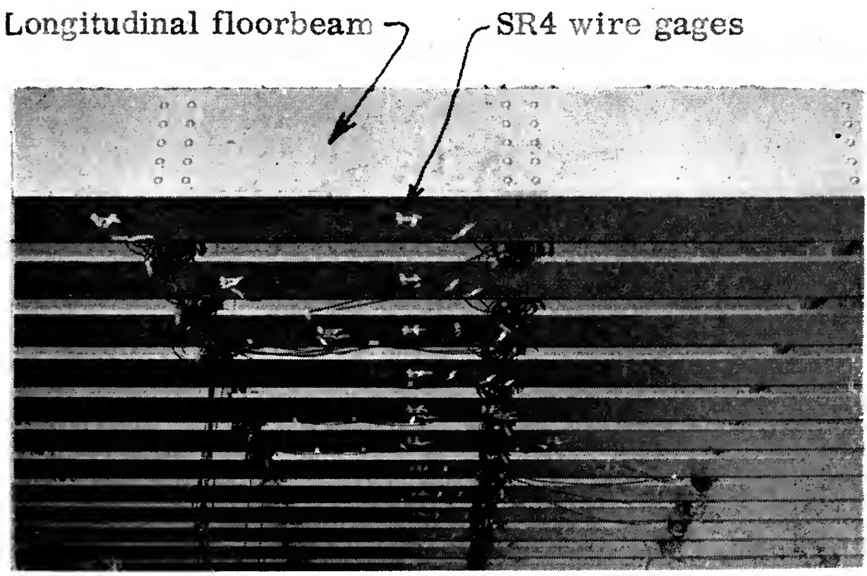


Fig. 2—General view of gages on longitudinal beams.

Fig. 3—General views of instrument truck near test bridge.

Texas Railroad bridge. In both bridges (see Figs. 43 and 53) it was found that with one track loaded the total load is distributed over all the beams supporting two tracks. The distribution of track load to longitudinal beams diminishes with the highest stresses induced in the beams under the loaded track, and a gradual reduction of stress to zero in the beams under the unloaded track, as shown in the diagrams on Fig. 53. The diagrams also illustrate that the simultaneous and maximum stress patterns are similar at high and slow speeds.

10. The stresses in the longitudinal beams on the NYC span were measured before and after the beams were encased in concrete. The results of this study are shown in Fig. 43, where it can be seen that encasement was beneficial in helping to distribute the axle loads more uniformly to all the beams. It also resulted in a reduction of the average stress in the beams due to the interaction of the concrete and steel.

B. FOREWORD

One of the assignments of AREA Committee 30—Impact and Bridge Stresses, is the determination of distribution of live-load axle weights to bridge floors consisting of either transverse beams or longitudinal beams. The transverse-beam type of floor is used in place of the stringer and floorbeam type where it is necessary to secure a minimum distance from base of rail to clearance. To secure data for this assignment, the AAR research staff arranged with several railroads to conduct tests on seven through-girder spans with the transverse-beam type of floor and on two spans having longitudinal beams.

The tests were conducted under regular scheduled trains, since the maximum stresses in the beams occurred under the locomotive drivers. Arrangements were made with the operating department of the railroads to have several of the trains cross the test bridge at about 5 mph, which is considered the same as static loading, and simultaneous readings were then secured on either 24 consecutive transverse beams, as shown in Fig. 1, or on the longitudinal beams, as shown in Fig. 2. Readings were also taken with the trains operating over the bridge at normal speeds to determine if there was any difference in the distribution between slow and high-speed trains. Readings were taken under both diesel and steam locomotives with the track in normal condition.

Since all the bridges were either over a highway or street, the AAR instrument truck was used for all the tests. In addition to housing the instruments, the top of the truck was used to mount the SR-4 gages, which eliminated the need for staging under the bridge, as shown in Fig. 3.

In conducting the tests on one of the spans with the transverse floorbeams, readings were taken with the bridge in normal condition, after which the diaphragms between the floorbeams were disconnected by removing the rivets. Additional readings were then taken. In one of the spans with the longitudinal beams, readings were taken before and after the space between the beams was filled with concrete.

The tests analyzed in this report were carried out under the general direction of G. M. Magee, director of engineering research, Association of American Railroads. The conduct of the tests, analysis of data, and preparation of the report were in charge of E. J. Ruble, research engineer structures, assisted by A. A. Sirel, assistant research engineer structures. Tests in the field were conducted by L. E. Monson, assistant structural engineer. The funds necessary for the tests were provided by the AAR.

C. INSTRUMENTS

Two 12-element oscillographs, each supplemented by its own power supply and amplifier units, were used in these tests. Strain measurements on the tested beams were made by means of SR-4 wire resistance gages. Power for the tests was provided by a Homelite gasoline-driven generator unit. A detailed description of the instruments and the set-up of wire resistance gages can be found in the AREA Proceedings, Vol. 52, 1951, page 152.

SR-4 strain gages having a gage length equal to 1 in were used throughout all the tests. Each gage was check-calibrated by means of a steel cantilever beam and weight of known physical properties. Thus, the recorded measurements can be considered accurate to within a small percentage.

The gage sensitivities, commonly known as stress factors, were expressed in psi per in of trace deflection on the oscillograms and varied from 2500 to 10,000 psi on the 9 bridges tested. A sensitivity of 2500 psi with a 1-in trace deflection represents a strain of 0.000083 in per in. in the steel, while a sensitivity of 10,000 psi with a 1-in trace deflection represents a strain of 0.000334 in per in, assuming a modulus of elasticity of steel equal to 30,000,000 psi.

All the recording instruments were housed as a permanent set-up in a custom-built truck owned by the AAR. This arrangement eliminates the use of a portable test house as well as the resetting of instruments when moving to a new test site. It also eliminates delays in the field testing when the recording equipment is shipped by express. The truck also provides a convenient scaffold for application of gages on beams, as shown in Fig. 3.

D. LOCOMOTIVES

On the 9 spans tested data were obtained from 99 diesel and 132 steam locomotives. a total of 231 locomotives. These locomotives, used by 8 railroads, include 12 different types and involve a great variety of loads. A general summary of the test locomotives, grouped by type and railroad, is given in Tables 1 and 2.

In general the tests were conducted under regular trains at normal speeds. However, speed restrictions were placed on a few of the trains to secure data under static conditions. On the Southern and M-K-T bridges, test trains were used to secure data under a full range of speeds in addition to data secured under the regular trains. For each span tested the locomotive type and number are given in the figures showing the test results.

The main object of this study is the distribution of axle loads on beams which are closely spaced; therefore, the primary items for study are the axle loads and axle spacing of the locomotives. These items and the grouping of locomotives by type and railroad are shown in Tables 1 and 2. Classification of locomotives relative to their use in passenger or freight traffic and also the counterbalance characteristics of the locomotives are not given in this report. Some of the locomotives contributed only a few runs to the tests, and although these test data are given in this report. the locomotive data are not included in the tables.

In the distribution of axle loads to transverse floorbeams, greater loads are contributed by the locomotive drivers. The main variations in axle loads and spacing of drivers, referring to Tables 1 and 2, are given below for a few locomotive types.

Mountain Type, 4-8-2

From the second part of Table 1 it can be seen that for the 4 groups of locomotives shown for this type, the driver axle loads vary from 61.4 to 68.5 kips, a variation of

11.6 percent of the smaller load. On B&O locomotives 5653–5661 the trailer axle load was 68.9 kips, greater than any driver axle load. Driver spacing varied from 6 ft to 6 ft 5 in.

Mikado Type, 2–8–2

In the third part of Table 1 the driver axle weights range from 56.4 to 63.1 kips for the 6 groups of locomotives of this type. Expressed as a percentage of the smaller axle load this represents a variation of 11.9 percent. The axle spacing for the drivers varied only 2 in.

Pacific Type, 4–6–2

The driver data for the 5 groups of Pacific type, 4–6–2 locomotives are shown at the bottom of Table 2. Driver axle loads varied between 50.5 and 59.3 kips, with a percentage variation of 17.4 relative to the smaller load. In this group a trailer axle load of 58.0 kips approached the maximum driver load of 59.1 kips for M-K-T locomotive No. 411. Spacing of the driver axles varied from 6 ft 3 in to 7 ft.

Diesel Locomotives—3-Axle Trucks

The 8 groups of locomotives shown at the bottom of Table 1 are composed of 3-axle diesels whose trucks are 30 ft 6 in, 34 ft 2 in, and 43 ft center to center. Their axle loads vary from 49.2 to 56.4 kips, a variation of 14.6 percent. The group has 2 axle spacings, namely, 7 ft ½ in and 7 ft 9 in. The principal difference in the length and axle spacing of the locomotives is due to the fact that they were manufactured by different companies, each using its own standards. Thus, American Locomotive Company uses 34 ft 2 in, the Electro-Motive Division of General Motors uses 43 ft and the Baldwin Locomotive Works uses 30 ft 6 in center to center of trucks.

Diesel Locomotives—2-Axle Trucks

In the 9 groups shown at the top of Table 2, the locomotive axle weights vary from 56.7 to 62.3 kips, a variation of 9.9 percent. Axle spacing in the majority of these locomotives was equal to 9 ft, with 9 ft 4 in shown for 2 groups only.

All data presented in Tables 1 and 2 were taken from locomotive diagrams furnished by the railroads. In general, axle loads shown are calculated values. Whenever it was necessary to use tender axle loads for calculations, the loads were adjusted for the actual amounts of fuel and water being carried at the time of test.

E. TEST SPANS AND LOCATION OF GAGES

Southern Railway Bridge (AGS) No. 139.3—Transverse Floorbeams

This structure, built in 1938, consists of a center and 2 outside through girders having an overall length of 58 ft 4½ in. The structure carries 2 tracks across 55th St. in Birmingham, Ala., and the floorbeams under the north track were selected for testing, as shown in Fig. 5. The girders carrying the north track are spaced at 17 ft 10½ in center to center of webs, and the transverse floorbeams, consisting of 18 WF 85 beams, are spaced at 23¾ in centers. The floor system has a row of diaphragms under each rail consisting of 15-in by ⅜-in plates connected to each beam by 2 angles, 3½ in by 3½ in by ⅜ in. The track ties supporting the rail rest on about 11 in of ballast. The ballast is supported by a 9/16-in steel deck plate riveted to the top of the floorbeams.

The strain gages were located on the bottom of the lower flanges of 24 consecutive floorbeams on the center line of steel, as shown by the top diagram of Fig. 5, with the center of the span between gages 10 and 11. In this manner the simultaneous and maximum stresses in a large number of floorbeams under locomotives operating over a complete range of speeds could be determined for any position of the locomotive.

New York Central Railroad Bridges—Transverse Floorbeams

Bridge No. C–38, Track 1

This single-track, outside span was built in 1947 across 38th St. in Chicago as a part of a widening program. It carries track 1 of the 5 main tracks. The through girders are 70 ft overall length, spanning the street and 2 sidewalks, and are spaced 15 ft 7¾ in center to center of webs. The outside girder was salvaged from another bridge. As shown in Fig. 11, the transverse floorbeams are 15 I 81.3 beams spaced at about 25¾ in center to center. A single line of diaphragms consisting of 10-in channels at 20 lb are connected to the beams with 3½-in by 3½-in by ⅜-in angles.

The floor is made up of ½-in steel plate resting directly on the floorbeams and suitably braced between beam flanges with narrow plates riveted to the floor plate. This type of floor plate is known as "floating floor plate." The floor plate is waterproofed and lined with concrete. The ties, spaced at about 17 in, are embedded in concrete.

The strain gages were located on the bottom of the lower flange of 24 consecutive floorbeams at the center line of steel, as shown by the top diagram of Fig. 11, with the center line of span between gages 12 and 13.

Bridge No. C–38, Track 3

This single-track, inside span carries track 3 of the 5 main tracks across 38th St. in Chicago. The span was originally built in 1895, but the floor system was rebuilt in 1921. The through girders are 70 ft overall length and are spaced at 13 ft 6 in center to center of webs, with both girders common to two tracks. The transverse floorbeams (see Fig. 14) are 12-in Bethlehem girder beams at 70 lb, spaced at about 25¾ in center to center. The floor system does not have any diaphragms between beams.

The floor consists of "floating" ⅜-in steel plate resting directly on the floorbeams. The 8-in by 8½-in ties are supported by 8-in by 9-in timber stringers at 6-ft centers. These stringers in turn are laid on 12-in by ⅝-in plates riveted to the floor plate. The whole top assembly is embedded in sand to the top of ties for fire protection.

The strain gages were located on the bottom of the lower flanges of 24 consecutive floorbeams on the center line of steel, as shown by the top diagram of Fig. 14.

Bridge No. 12½, North Track

This structure, built in 1924, consists of a center span of 39-ft ¼-in girders and two 17-ft 1-in end spans. The structure carries 3 tracks across Grand Blvd., in Gary, Ind. and the floorbeams under the north track were selected for testing. The girders (see Fig. 19) are spaced 11 ft 3 in center to center of webs, and the transverse floorbeams, consisting of 15 I 50 beams, are spaced at about 16-in centers. The girders were skewed 88 deg 1 min with the center line of street, but the floorbeams were constructed square to the girders. The floor system does not have any diaphragms between beams. The floor is of the ballasted type, that is, the track ties supporting the rail rest on about 24 in of ballast. The ballast is supported by a 6-in concrete liner which rests on a ⁵⁄₁₆-in steel plate on top of the floorbeams.

The strain gages were located on the bottom of the lower flanges of 24 consecutive floorbeams at the center line of steel, as shown by the top diagram of Fig. 19, with gage 12 on the center floorbeam of the span.

Bridge No. 259E, North Track

This structure, built in 1926, consists of two 93-ft 5-in skewed through girders with transverse floorbeams, as shown on Fig. 25. The structure carries 2 main-line curved tracks between Cincinnati and Sandusky across a highway, 2 Pennsylvania Railroad tracks and an Erie Railroad track and is located near Urbana, Ohio. The girders are spaced 30 ft 6 in center to center of webs, and the transverse floorbeams, consisting of 28-in girder beams at 175 lb, are spaced at 22½-in centers.

The floor system has 2 stringers per track consisting of 18-in Bethlehem beams at 64.5 lb spaced 5 ft 10½ in on centers, with 2 connection angles, 6 in by 6 in by ⅝ in, riveted to the floorbeams. Due to the closeness of the floorbeams only one tie was placed between beams. Superelevation for a 1-deg 51-min curve was provided by placing stringers at each rail at different elevations corresponding to high and low rail.

The strain gages were located on the lower flange of 24 consecutive floorbeams under the high rail of the westbound track, as shown in Fig. 25.

Baltimore & Ohio Railroad Bridge No. 58½—Transverse Floorbeams

This structure, built in 1936, consists of a 37-deg 5-min skewed center span having 2 girders 74 ft 7⅝ in center to center of bearings and 2 end spans with girders 16 ft 6 in center to center of bearings (see Fig. 29). The structure carries 2 main-line tangent tracks between Pittsburgh and Chicago across a 4-lane highway and sidewalks in Kent, Ohio. The girders are spaced at 31 ft 8 in center to center of webs, and the transverse floorbeams, consisting of 30 WF 172 beams, are spaced at 32½ in centers.

The floor system does not have any diaphragms between beams. The track ties rest on about 16½ in of ballast which is supported by a waterproofed reinforced concrete slab resting on top of the transverse floorbeams. The concrete slab is constructed with a 3-ply waterproofing membrane, a 3-in thick concrete wearing surface, and a reinforced concrete slab varying in thickness from 6 to 8¼ in.

The strain gages were located on the bottom of the lower flanges of 24 consecutive floorbeams under the south rail of the westbound track, as shown on Fig. 29.

Chicago & North Western Railway Bridge No. 1291, Track 4—Transverse Floorbeams

This bridge is a 7-track structure spanning the intersection of Lemoyne, Noble and Julian Sts. in Chicago. It is classified as an "old-style subway having been built in 1898 with the floorbeam connections reinforced in 1937." Each track is carried between 2 through girders with the inside girders common to the two adjacent tracks. The girders are spaced at 13 ft center to center of webs and vary in length up to 57 ft. The columns supporting the girders are made up of a web plate and 4 Z-bars.

The test track, eastbound track 4, with the essential details of the floor system, is shown on Fig. 33. Floorbeams spaced at 4-ft 9-in centers were built up from channels, web plates and cover plates. Trough-type stringers spaced at 4-ft 11-in centers were made up of angles, Z-bars and cover plates (see details, Fig. 33). The rails were laid on 6-in by 16-in oak timbers placed in the stringer troughs. Steel floor plate, discontinuous at the troughs, covered the area between girders. The built-up type of floorbeam and stringer, as shown on Fig. 33, was probably used because of the limited clearances at the bridge and also because of a lack of heavy rolled sections at the time of construction.

The strain gages were located on 24 consecutive floorbeams at the center line of track, as shown on Fig. 33.

Missouri–Kansas–Texas Railroad, Bridge No. D–789.9—Transverse Floorbeams

This structure, built in 1938, consists of two 97-ft 2⅞-in and two 24 ft 4⅝-in through girders, arranged as shown by the plan on Fig. 35. The structure carries a single 4-deg curved track across U. S. Highway 77 near Sterrett, Tex. The floorbeams at the north end of the bridge were selected for testing. The girders are spaced 19 ft 3 in center to center of webs, and the transverse floorbeams, consisting of 24 WF 74 beams, are spaced at about 19½-in centers.

The floor system has two rows of diaphragms consisting of 21-in by ⅜-in plates connected to each beam by 2 angles, 5 in by 3½ in by ⅜ in. The girders are braced against lateral forces by 12 WF 53 beams in a plane under the transverse floorbeams. The track ties rest on about 15 in of ballast under the low rail. The ballast rests on a waterproofed ⅜-in steel plate welded to the top flanges of the floorbeams.

The strain gages were located on the lower flanges of 24 consecutive floorbeams at the center line of steel, as shown on Fig. 35, with gage 24 located on the last floorbeam at the north end of the span. After completing these tests, gages 1, 2, 3, 22, 23 and 24 were removed from the floorbeams and placed on the lateral bracing as shown on Fig. 39.

New York Central Railroad Bridge No. 11½—Longitudinal Beams

This structure, built in 1907, consists of 4 longitudinal beam spans, with the beams in the end spans having an overall length of 22 ft 5 in and those in the interior spans having an overall length of 20 ft. The structure carries 2 main-line tangent tracks over Virginia St. in Gary, Ind. The spans consist of ten 20 I 65 beams, twelve 18 I 55 beams and one outside spandrel girder per track, as shown on Fig. 43. The track ties rest on about 13 in of ballast which is supported by a 10-in waterproofed reinforced concrete slab resting on top of the beams.

The beams in each span have 4 transverse rows of diaphragms, 2 rows near the ends of the span and 2 near the third points, consisting of 10 I 25 beams with the flanges riveted to the webs of the longitudinal beams. A series of tests were conducted with the bridge as described above, after which the space between the beams was completely filled with concrete. Additional tests were then conducted on the beams after a period of about three weeks.

The strain gages were located on the lower flanges of the north spandrel girder and on 23 beams at the center of the east span, as shown on Fig. 43.

Missouri–Kansas–Texas Railroad Bridge No. D–773—Longitudinal Beams

This structure, built in 1940, consists of four 54-deg skewed longitudinal beam spans with 13 beams per span. The 2 end spans are 44 ft center to center of bearings and the 2 center spans are 47 ft 7 in center to center of bearings (see Fig. 53). The structure carries one main-line tangent track and one passing track over State Highway 246, near Dallas, Tex.

The thirteen 36 WF 230 longitudinal beams in each span are spaced at 24-in and $24\frac{15}{16}$-in centers. The beams have transverse rows of diaphragms spaced at 5 ft 2½ in and consisting of 2-ft 7-in lengths of 24 WF 87 beams, with the flanges riveted to the webs of the longitudinal beams. The track ties rest on about 11 in of ballast, which is supported by a ⅜-in steel plate welded to the tops of the beams.

The strain gages were located on the lower flanges of the 13 beams of the south span. Gages were located on 2 lines, 1 perpendicular to the center line of track and the outer at an angle of 54 deg with the center line of track, as shown in the partial plan on Fig. 53.

F. FIELD RECORDS

Description

The test records, or oscillograms, were photographed on sensitized paper 10 in wide and 200 ft long. Two oscillographs, marked A and B, were used for each test so that the stresses at 24 different locations were recorded simultaneously. Each oscillogram was marked with the name of the railroad, bridge number and date. The oscillograph letter and run number, which are photographed on the oscillogram after each run, refer to the log of test runs which shows the engine number, direction, approximate speed, type of train, and all other necessary information regarding the test runs. The inclusion of all the test records, consisting of 452 oscillograms from 127 tests under the steam locomotives and 99 tests under the diesel locomotives, with a total of about 11,000 individual traces, would make this report too voluminous. Thus, only typical oscillograms for a slow and high-speed run, as recorded by the "B" oscillograph, are reproduced in this report (see Fig. 4) for a steam locomotive passing over a Southern Railway bridge. The remaining oscillograms are on file at the AAR Research Center, Chicago.

Each oscillogram on Fig. 4 consists of three parts: the left portion, which was taken before the train was on the span, the middle portion, which shows the traces produced by the locomotive and tender crossing the span, and the right portion, taken after the train was completely off the span. On the top and bottom of the oscillograms there are vertical time lines calibrated in 0.01, 0.10 and whole seconds, as shown by dimensions on Fig. 4. The heavy horizontal lines at the top and bottom were broken when the train wheels contacted the wheel markers, which were described in the AREA Proceedings, Vol. 46, 1945, page 205. The two wheel markers were located, as shown in "Section at Center Line of Track," on the north rail, one at 2 ft 4 in east and the other at 85 ft 8 in west of center line of span. Thus, the total distance between wheel markers was 88 ft, or 1/60 of a mile. This distance was also used in clocking trains to determine the approximate speed during test runs. The "A" and "B" oscillographs were tied together electrically through the use of time lines and wheel markers so that any instant of time or any position of the train on the span can be accurately located on both oscillograms. From a study of the oscillograms shown on Fig. 4 it can be seen that there is a difference in the traces at 8.0 and 43.6 mph. The traces at 8.0 mph are smooth and reveal 4 distinct wave patterns induced by the group of driver loads, the trailer axle loads and the 2 groups of tender axle loads. At 43.6 mph the traces show large vibrational effects due to the loads passing over the floorbeams; however, the same 4-wave pattern is still evident.

Reading of Oscillograms

The oscillograms were oriented for reading by placing them with the run number at the right, as shown on Fig. 4. On runs B13 and B16 (see Fig. 4) the first trace at the top was made by the gage on floorbeam 13, while the last trace was made by the gage on floorbeam 24. Matching oscillograms A13 and A16, not shown in this report, have a similar layout for the gages on floorbeams 1 through 12. Traces 1 to 12 represent floorbeams 1 to 12 on "A" oscillograms and floorbeams 13 to 24 on "B" oscillograms. In these tests the polarity of the gages was such that an upward deflection of the trace on the record indicated tension in the steel.

Base lines, or lines of zero load, were established by joining the short trace lines at either end of the oscillogram. Since the traces vary in width, base lines are drawn from one side of the trace, usually the side towards which the trace deflects.

In the tests on transverse floorbeams two readings were taken from each trace on each oscillogram; one at the point of maximum deflection of each trace as the train passed over the span, and the other simultaneous for all 24 traces when the trace deflection at the center beam, usually floorbeam 13, was maximum. The trace deflections, measured to 0.01 in, were multiplied by 5.00 ksi, the stress factor for this particular bridge test, thus obtaining the unit stress at each gage location. An illustration of the above procedure of reading oscillograms is given on Fig. 4 where maximum stress readings are shown for floorbeams 13 and 19. Also shown are the lines used for reading simultaneous stresses in the 24 beams. A complete tabulation of stresses is shown on Figs. 6 and 7.

It should be noted that in the analysis of bridge test data from oscillograms, ordinarily three groups of stresses are obtained: namely, maximum stresses, semi-amplitudes and mean stresses. Stresses for slow-speed runs (less than 10 mph) are considered as static stresses. In these tests semi-amplitudes were not determined and all the recorded stresses are either maximum or simultaneous readings. The correction for semi-amplitude in static stresses was small. For example, in run B16 on Fig. 4, the semi-amplitude stress for floorbeams 13 and 19 is equal to 0.10 ksi, which is only 1.8 and 2.5 percent, respectively, of the maximum stresses recorded in these beams.

The use of wheel markers, which produce breaks in horizontal lines at the top and bottom of the oscillograms, makes it possible to determine accurately the speed of a locomotive and also the position of a locomotive on the span for any instant of time on the oscillogram. The wheel markers were connected in the electrical circuit so that the east marker produced breaks at the top of the oscillogram while the west marker produced breaks at the bottom. The train speed is calculated by counting the time in seconds which is required to traverse the distance of 88 ft between the east and west wheel markers. For example, in run B16 on Fig. 4 this time lapse was 7.53 sec, which equals 11.7 ft per sec, or 8.0 mph. Also illustrated on Fig. 4 is the determination of the locomotive position on the span which corresponds with the maximum stress in floorbeam 13 and the line of simultaneous stresses. It can be seen from run B16 that the maximum stress in floorbeam 13 and the simultaneous stresses in the other 23 beams occurred 0.75 sec after the first driver "tripped" the east wheel marker. This places the first driver 8.8 ft west of the east marker or 6.5 ft west of the center line of span. Similar examples of determination of speed and locomotive position are shown for run B13 on Fig. 4.

G. TEST RESULTS ON TRANSVERSE FLOORBEAMS

Presentation of Data

The test results on transverse floor beams are shown on Figs. 5 to 42, incl., which are grouped in consecutive order by bridges. The first drawing of each group, such as Figs. 5, 11, 14, etc., includes general details of the span and test members, location of gages, and two typical diagrams of the recorded maximum and simultaneous stresses for two runs made by the same locomotive, one for a slow speed and one for a higher speed run. Maximum stress as reported herein is the greatest stress recorded at a floorbeam under passage of a locomotive. Simultaneous stress as reported herein was the stress which existed in each of 24 floorbeams when the stress in one of the middle beams, usually No. 13, was maximum.

The other drawings in a group, such as Figs. 6, 7, 8 and 9 for the Southern bridge, contain tabulated values of "Recorded Stresses in Transverse Floorbeams." These figures contain two parts: a "Section on Center Line Between Girders" showing the size and spacing of floorbeams tested, and below this, the test results which are arranged in tabular form with self-explanatory headings. The test results are grouped by locomotive type and order of speed. The locomotive position on the span for simultaneous stresses is shown for each run relative to the center line of span. Distances shown are to the first driver for steam locomotives and the first axle for diesel locomotives. The data for each test run include the maximum stress, simultaneous stress and the ratio of the recorded maximum stress to the average recorded maximum stress. The terms "Static" and "Dynamic" are defined in the notes found at the bottom of each tabulation.

Static Stresses and Distribution Factors

A summary of the recorded and calculated static stresses in transverse floorbeams, as plotted and tabulated on Figs. 5 to 42, incl., is shown in Table 3. Stresses recorded under slowly moving trains (less than 10 mph) are usually considered as static stresses. The range of speeds for the static runs is shown in Col. 6 of Table 3. It should be noted that a 17.7 and 18.8 mph run have been included with the NYC 70-ft girder span track 3 data because of a lack of slower-speed runs on that span; however, the recorded stresses at these speeds were low. The C&NW tests shown on Figs. 33 and 34 are not included on Table 3, because there were no runs at speeds less than 28 mph. The static stresses are shown for six single track and two double-track bridges (see Col. 1). Cols 2 and 3 give the railroad, span and description of the floor system, while Col. 4 is a reference to the figure numbers where details and test results are shown. Essential data concerning the locomotive types shown in Col. 5 can be found in Tables 1 and 2. Col. 7 lists the average recorded maximum stress for all 24 transverse floorbeams tested, while the calculated stresses shown in Col. 8 are based upon the current AREA design specifications relative to axle load distribution on transverse floorbeams. The experimental distribution factor "K_E", shown in Col. 9, was obtained by correcting the specified distribution factor "K" by the ratio of the recorded to the calculated stress. Col. 10 illustrates the maximum percentage variation of either the largest or smallest stress in 24 floorbeams from the average recorded maximum static stress.

The effect of diaphragms on stresses in transverse floorbeams can be seen from a study of the test results for the NYC 70-ft girder span track 1 (refer to Col. 7 of Table 3). Under the same 3-axle diesel the recorded static stress varied from an average of 3.11 ksi for 5 runs with diaphragms connected, to an average of 3.34 ksi for 7 runs with diaphragms disconnected. The difference of 6.8 percent in the average stress indicates some advantage in using diaphragms. This point can also be noted in the recorded static stresses on the Southern and CB&Q spans for locomotive type 2–8–2. Although there is a difference in floorbeam weights and spacing and depth of ballast, one of the main reasons why the average recorded static stress on the Southern span was only 4.53 ksi compared to 7.07 ksi on the CB&Q span was probably due to the double line of diaphragms on the former span. A study of Cols. 9, 10 and 11 indicates that the use of diaphragms has no particular effect on the "K_E" and the maximum variation of stresses.

A comparison of the recorded stresses for tracks 1 and 3 of the NYC 70-ft span indicates an average static stress of 3.24 ksi for 12 runs under a 3-axle diesel on track 1, and a static stress of 4.62 ksi for 1 run of the same locomotive on track 3. The difference may be due to the use of shallower beams on track 3 as well as a difference in floor construction: ½-in concrete-lined steel plate was used at track 1, while ⅜-in steel plate was used at track 3. However, since only 1 run at a speed of 17.7 mph was secured under a 3-axle diesel on track 3, it is not feasible to further analyze the difference in static stresses.

A study of Col. 7 for the 4 remaining single-track bridges illustrates that the recorded static stresses in the NYC 39-ft ¼-in span were from 1.70 to 2.56 ksi less than the calculated static stress, while the recorded values for the CB&Q span varied from 0.60 ksi less to 0.17 ksi more than the calculated values. The large difference in the ratio of recorded to calculated static stress in these two bridges is undoubtedly due to the difference in their floor construction. The NYC span has a ⁵⁄₁₆-in concrete-lined steel floor plate with 2 ft of ballast, while the CB&Q span has a ⅜-in wrought iron floor plate with only 5 in of ballast and no concrete liner.

The results of tests on the B&O and NYC double-track bridges are shown at the bottom of Table 3. It is evident that the 6-in reinforced concrete slab and heavy ballast on the B&O span accounts for the large difference between the recorded and calculated stresses shown in Cols. 7 and 8. The average recorded stress in the B&O span was only 49 percent of the calculated stress, while that in the NYC span was 93 percent of the calculated stress. The low recorded stresses in the B&O span were evidently due to the composite action of the 6-in concrete slab and the floorbeams which were not considered in the calculated stresses. The average experimental distribution factor "K_E" is equal to 0.62 for the B&O span and 1.14 for the NYC span, as compared with the AREA design specification value of 1.25 for double-track bridges.

A review of the values tabulated in Col. 10 of Table 3 indicates that the maximum stresses in some floorbeams varied from as much as 59 percent less to 57 percent greater than the average maximum stress in the 24 floorbeams tested. This large variation between the stresses recorded in individual floorbeams is probably due to unequal bearing. Experience from previous testing has indicated that only one out of every six to eight ties can be expected to have full bearing.

Comparison of Recorded and Calculated Static Stresses

Stresses in closely spaced floorbeams can be calculated by application of a method which was developed by Dr. A. N. Talbot for the determination of rail stresses. In this method the rails are considered as continuous beams which are supported on elastic track ties. The elastic supports, or ties, exert vertical forces upward on the rails, causing bending moments. The following physical properties are required in order to calculate the rail stresses: The modulus of elasticity of rail steel, E; the moment of inertia of the rail, I; and the track modulus, U, expressed in pounds per inch of rail length per inch of depression. A description of the method of computation and the derived formula can be found in the AREA Proceedings, Vol. 19, 1918, page 878. Coefficients which facilitate the calculations were published later as "Cofficients of Bending Moments in Rail" in the AAR Counterbalance Test Bulletin, March 1944, page 45.

By extending the method referred to in the preceding paragraph to the calculation of stresses in transverse floorbeams, it can be seen that the track ties are exerting vertical downward pressures on to the floor plate which, in turn, transmits the pressure to the floorbeams. Pressure transmitted to a floor plate will be in pounds per foot of track and can be determined at any point which may be affected by a locomotive axle load. This method was employed to calculate the static stresses under steam and diesel locomotives on the Southern Railway bridge. The results are shown on Fig. 10. In the calculations, the track modulus, U, was assumed equal to 1500 pounds per inch of rail length per inch of depression.

The axle loads and positions shown on Fig. 10 produced maximum stress in floorbeam 13, which was selected as a reference beam. The locomotive positions and the complete simultaneous stresses in the 24 floorbeams which were used in Fig. 10 are shown in Fig. 6, run 15, and Fig. 7, run 19, for the steam and diesel locomotives, respectively.

The middle diagrams on Fig. 10 shows the vertical pressures which are transmitted from the ties to the floor plate. The 24 consecutive floorbeams were plotted as the abscissa of these diagrams. The pressures, in kips per foot of track, were calculated at each beam and plotted as the ordinate. Pressures plotted above zero were downward or positive, and pressure plotted below zero were upward or negative. The pressures at the 24 floorbeams due to each individual axle load were plotted as small open circles and connected by light dashed lines. The pressure curves for axles 1 to 8, incl., of the steam locomotives are shown in the left diagram, while the curves for the diesel locomotive axles 1 to 7, incl., are shown on the right diagram.

It can be seen that each axle load as calculated spreads over all 24 beams, producing maximum pressure at the nearest beam and diminishing pressures at the beams to either side of the axle, with an uplift on the outer beams in the group. For example, axle 4 of the steam locomotive (see left diagram, Fig. 10) exerted a maximum positive pressure of 7.77 kips per ft at floorbeams 13 and small negative pressures at floorbeams 5 to 8 and 18 to 23, incl. It appears that the spread of an individual steam or diesel axle load in the positive pressure range was confined to 9 beams for this particular span. The vertical pressures on each floorbeam were summed up and the total pressures were plotted with solid circles and heavy lines. For example, referring to the left diagram, the total vertical pressure at floorbeam 13 due to loads from axles 1 to 6, incl., was 11.35 kips per ft. Similarly, the total vertical pressure at floorbeam 13 due to the diesel locomotive axle loads 3 to 6, incl., was 8.16 kips per ft (see right diagram).

It is interesting to compare the above calculated total pressures per foot of track with the live load per foot of track obtained by dividing the individual axle loads by the axle spacing. For example, the steam locomotive axle load of 60.2 kips from axle 4 divided by the axle spacing, 5 ft 7 in, equals 10.8 kips per ft as compared with 11.35 kips per ft calculated total pressure. Similarly, the diesel locomotive axle load of 62.0 kips divided by 8 ft 10 in equals 7.02 kips per ft as compared with 8.16 kips per ft of track calculated total pressure. Expressing the difference in percent of the calculated total pressure, the axle loads per foot of track are 4.8 and 14.0 percent below the calculated pressures for the steam and diesel locomotives, respectively.

In the lower diagrams of Fig. 10, the recorded simultaneous stresses in the 24 floorbeams are compared with the calculated total pressures for each beam. The recorded values are shown by open symbols connected by dashed lines. The load on each beam was obtained by multiplying the corresponding calculated total pressure in kips per foot of track, given in the middle diagrams, by the beam spacing, 1 ft 11¾ in. This load was considered uniformly distributed over a length of 10 ft, or about equal to the length of the tie plus depth of ballast. Using the loads and distribution given above, the stresses were calculated for each of the 24 beams and plotted on the lower diagrams of Fig. 10. A comparison of the recorded and calculated stresses on these diagrams reveals close agreement, with the calculated stresses a little higher than the recorded stresses in most cases. The maximum calculated stress for the steam locomotive is equal to the recorded maximum (see floorbeam 13), while the calculated maximum for the diesel locomotive is only 8 per cent less than the recorded maximum of 4.35 ksi.

Stresses at High Speeds

Referring to the first figure in each bridge group, such as Fig. 5 for the Southern Railway bridge, the maximum stresses in ksi were plotted as the ordinate against the 24 floorbeams as the abscissa on the diagrams entitled "Maximum Stresses." In general, the maximum stress diagrams show the stress variation in the 24 floorbeams for a slow speed or static run, and a high-speed run for the same type of locomotive. In Fig. 5, for example, the maximum stress curves reveal a similar pattern for a static run at 3.0 mph and a high-speed run at 43.6 mph for a 2–8–2 type locomotive operating over the span. The maximum stress curve patterns were similar for slow and high-speed runs in most of the spans tested, with the high-speed stresses greater than the low-speed stresses, as would be expected. The AREA design static and dynamic stresses are also included on all maximum stress diagrams. The maximum calculated stresses in these transverse beam tests are higher than the average maximum recorded stresses. Even the greatest recorded maximum stresses, such as 9.20 ksi for a steam locomotive operating over a C&NW span (see run 129, Fig. 34), and 6.80 ksi for a diesel locomotive operating over a NYC span (see run 13, Fig. 15) are 31.9 and 7.1 percent lower than the corresponding calculated stresses of 13.52 and 7.32 ksi.

At this point it is well to mention that the calculated stress of 13.52 ksi obtained on the C&NW bridge (Figs. 33 and 34) was computed in accordance with the AREA design specification for distribution of axle loads on transverse beams without stringers, and that the effect of the trough-type stringers was neglected. If a full axle load were used on each floorbeam, and the 4-ft 9-in beam spacing would justify doing this, then the calculated stress in the floorbeams would be 17.1 ksi. It can be seen that both methods of calculating the stress result in a value which is considerably greater than the maximum recorded stress of 9.20 ksi in floorbeam 19 for run 129 on Fig. 34. It is evident from the foregoing considerations and from the study shown on Fig. 10 and discussed previously that the proper procedure to follow in calculating the stresses in the floorbeams of this structure should involve the continuity effect of the rails. It can be seen from these tests that considerable error is introduced when calculating the stresses in floorbeams with large spacing if the stresses are calculated from pressures determined by dividing the axle loads by the axle spacing.

The lower diagrams on the first figure in each bridge group, such as Fig. 5 for the Southern Railway bridge, show a graphical comparison of the simultaneous stresses measured in each of 24 floorbeams when the stress was maximum in floorbeam 13. The same slow and high-speed runs were used to illustrate the simultaneous stresses as were used in the diagrams for maximum stresses. Generally, the two curves indicate the same pattern of stress distribution at high speed as at low speed.

It has been pointed out previously that floorbeam 13 was selected as a reference beam from which the simultaneous stresses were read in the group of 24 beams. This does not necessarily mean that the stress in beam 13 was the maximum recorded stress for the group of 24 floorbeams. The maximum stress may occur in any one of the 24 beams and depends on many factors, such as the bearing, type of floor system, etc.

Total Impacts

In the four single and two double-track bridges where the stresses were recorded under a full range of speeds, the total recorded impacts were determined and plotted as shown on Fig. 42. Each of the six bridges is represented by a different symbol, with the impacts from diesel locomotives shown in the left diagram and those from steam locomotives shown in the right diagram. The total impacts represent the difference between the average maximum static stress and the average maximum stress at speeds higher than 10 mph. The difference is expressed as a percentage of the average static stress. For example, referring to runs 12 and 16 of Fig. 22, the recorded average stress (static) for run 12 was 1.75 ksi, while the recorded average stress for run 16 was 2.90 ksi. The difference, 1.15 ksi, is the total impact at a speed of 81.7 mph, and expressed as a percentage of the static stress (1.75 ksi) is equal to 65.6.

Fig. 42 on total impacts also includes the AREA design impact values which were computed from the specifications for single and double-track structures. The gages for single-track spans were located near or at the center line of track; therefore, by virtue of this location, the roll effect for single-track spans is negligible. For double-track spans the roll effect amounted to 5.4 percent. This difference due to roll effect accounts for the higher design impact values shown on Fig. 42 for double-track spans.

From Fig. 42 it can be noted that the total impacts recorded for the NYC 39-ft ¼-in span exceeded the AREA design values in many cases for both diesel and steam locomotives. The lowest recorded total impacts were obtained from the B&O and NYC double-track spans.

Variation of Maximum Stresses in Individual Beams

Referring to the figures entitled "Recorded Stresses in Transverse Floorbeams", the variation of the recorded maximum stress for each floorbeam from the average recorded maximum stress for the 24 beams is tabulated under the column heading "Ratio." The ratio shown indicates whether the individual maximum stress is greater or less than the average stress by virtue of being greater or less than unity. The maximum stress variation in individual floorbeams occurred in the NYC 39-ft ¼-in span. A maximum variation of 59 percent less than the average recorded maximum stress took place in floorbeam 12 under run 16 for a locomotive type 4–8–4 (see Fig. 22). The maximum variation greater than the average stress occurred in floorbeam 1, run 14, for a 3-axle diesel and amounted to 57 percent, as shown in Fig. 20. It appears that these variations in stress are not affected by locomotive speed.

Stresses Under Tender Axle Loads

Stresses were recorded in 24 consecutive floorbeams on 2 NYC spans under the passage of tender axle loads, as shown in Figs. 22 to 24, incl., for the 39-ft ¼-in span, and Figs. 26 to 28, incl., for the 93-ft 5-in span. Three runs were recorded on each span, and a maximum stress of 4.50 ksi occurred in floorbeam 19 of the 93-ft span (see run 12, Fig. 26). The tender causing maximum stress had 6 axles and a total weight of 237 kips. The average maximum stress for the tender was 3.04 ksi as compared to 3.34 ksi recorded under the engine loads. For this particular run (run 12, Fig. 26) the average stress under the tender was 9 percent less than the average stress under the engine. For the other 2 runs on the 93-ft span, the average tender stress was 5.5 and 6.6 percent lower than the average maximum stress under the engine. On the 39-ft span the average maximum tender stress varied from 0.4 to 24.6 percent less than the average maximum stress under the engines. The maximum variation from the average stress was 58 percent, as shown for floorbeam 16, run 2, Fig. 22.

Stresses Under Freight and Passenger Cars

Recorded stresses in transverse floorbeams were obtained under freight cars for one run on the Southern Railway span and 2 runs on the NYC 93-ft span. The results are tabulated in Figs. 8, 27, and 28. The average maximum recorded stresses under the freight cars were about one-third of the average maximum stresses for the locomotives of the same train.

The test results obtained under passage of a passenger car with 3-axle trucks are shown for run 26 in Fig. 21. The average maximum recorded stress of 1.25 ksi for this particular passenger car was 31 percent less than the corresponding average of 1.81 ksi for the diesel locomotive in the same train.

Stresses in Bottom Laterals

On the M-K-T 97-ft span (see details on Figs. 35 and 39) the stresses were measured in the two end laterals by strain gages located on the diaphragm lines and the center line of steel. The test results on these laterals are shown in the tables at the bottom of Figs. 40 and 41. The simultaneous stresses in the laterals were read at the instant the maximum stress occurred in floorbeam 13. The maximum stresses were the greatest stress recorded at a particular gage location for each run. The average stress shown in the tables at the bottom of Figs. 40 and 41 is the algebraic average of the maximum stresses recorded in two laterals which consisted of six sections. It is interesting to study the simultaneous stresses in the laterals which are shown graphically in the top left diagram of Fig. 39. Also shown in this diagram are the maximum stresses and the position of the locomotive for maximum and simultaneous stresses at Sections A–A to F–F and floorbeams 4 to 21, incl. The variation of the simultaneous stresses at the three gage locations on each lateral indicate that the stresses are dependent on the deflection of the floorbeams. This can be noted from the simultaneous stresses plotted for Sections A–A, B–B and C–C where axle 1 is located above floorbeam 5 and near Section C–C. The simultaneous stress was greatest at Section C–C and became progressively smaller as the distance along the lateral from axle 1 increased. Data shown for Sections D–D, E–E and F–F also demonstrate the effect of floorbeam deflection on stresses in the laterals, namely, that the stresses at these sections are almost equal, coincident with the locomotive position shown at the top of the diagram. As the locomotive passed over the span there was a reversal of stress, causing many maximum compressive stresses which are shown with a minus sign in the tabulations. Five out of the six maximum stresses recorded for run 34, shown on Fig. 40, were compressive. It should be kept in mind that these maximum stresses on the individual sections were recorded at different positions of the locomotive. The highest tensile stress recorded was 3.40 ksi at Section E–E under a steam locomotive at 38.1 mph (see run 21, Fig. 41), while the highest compressive stress was 1.50 ksi at Section C–C for a 3-axle diesel at 47.6 mph (see run 34, Fig. 40).

H. TEST RESULTS ON LONGITUDINAL BEAMS

Presentation of Data

The test results on the longitudinal beams for the NYC and M-K-T double-track bridges are shown on Figs. 43 to 52, incl., and Figs. 53 to 60, incl. The first figure for each group, Figs. 43 and 53, show the general details of the spans, the location of gages and the numbering of the beams. Also shown on these two figures are diagrams illustrating the simultaneous and maximum stresses recorded for a few test runs. The remaining figures in each bridge group, such as Figs. 44 to 52, incl., for the NYC tests, show the test beams and their relation with respect to the test track. Also included in tabular form are the recorded stresses for all test runs.

A visual inspection of the oscillograms indicated that the maximum stresses in 24 floorbeams generally occurred simultaneously at slow-speed runs; however, at high speeds the maximum stress in the outer beams did not reach a maximum until a fraction of a second after the maximum stress occurred in the beams under the rails. The values shown in Col. 3 marked "Time Lag" are the time intervals in seconds between the occurrence of the maximum stress in a beam and the maximum stress in a reference beam near or under the rail. Beams 17 and 4 were used as reference beams for the NYC and M-K-T bridges, respectively. For example, when a 3-axle diesel crossed the NYC span at 59 mph (see run 3, Fig. 44), a stress of 0.25 ksi was recorded in beam 1 simultaneously with a maximum stress of 2.60 ksi in beam 17; however, 0.02 sec later a maximum stress of 0.50 ksi was attained in beam 1.

Static Stresses and Distribution of Loads

A study of the data presented on Figs. 43 to 60, incl., indicates that the stresses recorded in the longitudinal beams under slowly moving locomotives were considerably lower than those calculated. For example, the recorded maximum stress in beam 13 of the NYC bridge was 2.65 ksi for run 7 at 4.5 mph, compared with a calculated static stress of 3.96 ksi. The calculated stresses are based upon a uniform lateral distribution of live load over a distance of 13 ft. The calculated AREA design values shown on the figures are for the 10 deeper beams directly under the track. It is evident from the center diagram on Fig. 43 that the lateral distribution of live load exceeded that assumed, since all 24 beams were carrying load with the westbound track loaded. The low recorded stresses might also be due to the concrete deck and longitudinal beams acting as a composite section.

On the NYC bridge two sets of data were secured; the first with the beams "Before Reinforcing", as shown on Figs. 44 to 47, incl., and the second with the beams "After Reinforcing", as shown on Figs. 48 to 52, incl. The effect of reinforcing, which consisted of filling the spaces between the beams with concrete, resulted in considerable reduction of the recorded stresses. The highest maximum static stresses before reinforcing were 2.65 and 4.55 ksi for diesel and steam locomotives, respectively, (see Fig. 44 and 47). After reinforcing, referring to Figs. 48 and 50, the highest maximum static stresses amounted to only 0.90 and 1.25 ksi for diesel and steam locomotives, respectively. This reduction in the recorded static stresses to approximately one-third its original value before reinforcing is illustrated graphically on Fig. 43 for a 3-axle diesel crossing the span before reinforcing at 4.5 mph and after reinforcing at 10.5 mph. Also shown on Fig. 43 are the average maximum stresses before and after reinforcing. The average maximum stress was reduced from 1.36 ksi before reinforcing to 0.64 ksi after reinforcing, a reduction of 53 percent. The effect of the reinforced concrete floor slab was neglected when calculating the static stresses for the "Before Reinforcing" condition. This resulted in the higher calculated static stresses of 3.96 and 5.02 ksi for the diesel and steam locomotives which produced the maximum recorded static stresses of 2.65 and 4.55 ksi. These calculated stresses were 90 and 47 percent greater than the average maximum recorded static stresses in beams 10 to 19, incl.

The diagrams of maximum and simultaneous stresses shown on Fig. 53 for the M-K-T bridge indicate that with one track loaded the stresses vary quite uniformly from a maximum at beam 1 to about zero stress at beam 12. The average recorded maximum stress under passage of locomotives at slow speeds was considerably lower than the calculated stress. For example, when the M-K-T locomotive 411 passed over the span at 6 mph, the maximum recorded stresses at Section A–A varied from 2.70 ksi in beam 1 to zero stress in beam 12, with an average stress of 1.24 ksi (see run 15, Fig. 57). The calculated stress, based upon the assumption that the axle loads are distributed equally to 6 beams, is 4.04 ksi. It is evident from the data presented that even if both tracks were loaded, the actual stress in the longitudinal beams under the rail would be less than those calculated. For example, in run 15 the maximum stress in beam 4 with the test track loaded was 2.15 ksi, while the stress in beam 10, which is comparable to beam 4 and under the other track, was 0.25 ksi. If both tracks were loaded the resulting stress in beam 4 or 10 would be the sum of the stress in each beam with one track loaded, or 2.40 ksi, as compared with a calculated stress of 4.04 ksi.

The time lag between the simultaneous and maximum stresses shown in Figs. 54 to 60, incl., for the M-K-T span is due principally to the 54-deg skew of the bridge and the sections on which the gages were located. There does not appear to be any consistent pattern to this time lag even though consideration was given to the difference in northbound and southbound trains.

Stresses at High Speeds

A comparison of the stresses recorded in the longitudinal beams of these two bridges under passage of diesel and steam locomotives indicates that the pattern of stress distribution to the beams is similar for slow and high speeds, with some increase in the magnitude of stress at the higher speeds. For example, the data shown on Fig. 47 for run 6 at 6.2 mph and run 15 at 40.7 mph indicate that the ratio of recorded maximum stress to average recorded maximum stress is approximately the same at the two speeds. Furthermore, this ratio for beam 13 on the NYC span before reinforcing varied only from 1.71 to 2.16 throughout a full range of speeds from 4.5 to 75.6 mph.

I. OBSERVATIONS

As a result of these tests on transverse floorbeams and longitudinal beams under diesel and steam locomotives, it would appear reasonable to make the following observations:

1. Values of "K" provided in Sec. A (Art. 19) of the AREA Specifications for Steel Railway Bridges are in line with test results for open track or track with minimum ballast and floor plates.

2. Some reduction of factor "K" can be made where a concrete slab is used instead of, or in addition to, a floor plate, or where the depth of ballast exceeds 10 in.

3. The recorded stresses in the longitudinal beams tested were less than those calculated due to a number of indeterminable causes. It would appear that further tests are needed if it is felt that provisions for distribution of load in the design specifications should be changed.

4. If a system of longitudinal beams is encased in concrete, a reduction in calculated stress can be made, taking into account the interaction of steel and concrete. This also applies when the longitudinal beams support a concrete slab.

J. ACKNOWLEDGEMENT

The Committee on Impact and Bridge Stresses and the American Railway Engineering Association are indebted to the officers of the B&O, CB&Q, C&NW, M-K-T, NYC and Southern for their cooperation in conducting these tests.

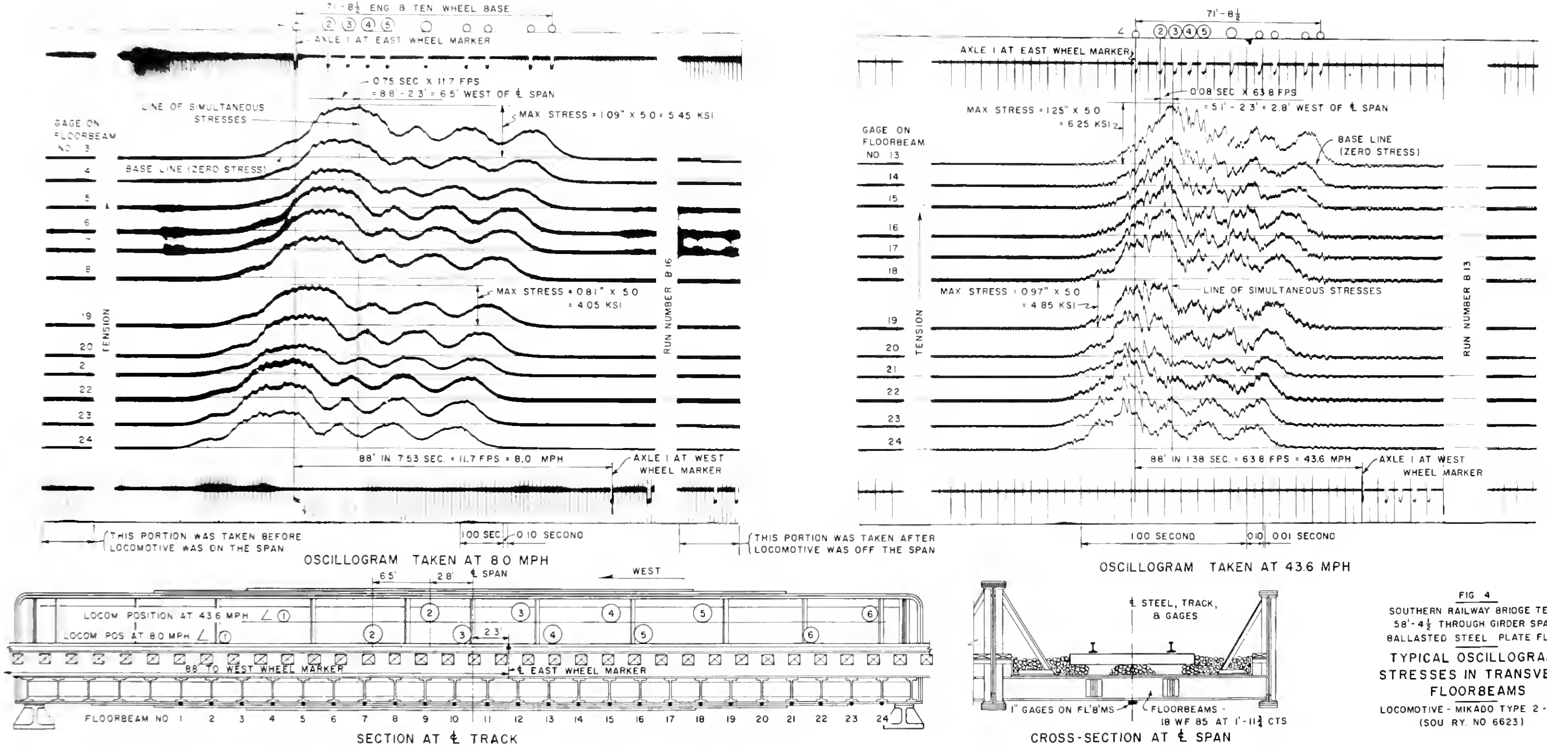


FIG 4
SOUTHERN RAILWAY BRIDGE TESTS
58'-4½ THROUGH GIRDER SPAN
BALLASTED STEEL PLATE FLOOR

TYPICAL OSCILLOGRAMS
STRESSES IN TRANSVERSE
FLOORBEAMS

LOCOMOTIVE - MIKADO TYPE 2-8-2
(SOU RY NO 6623)

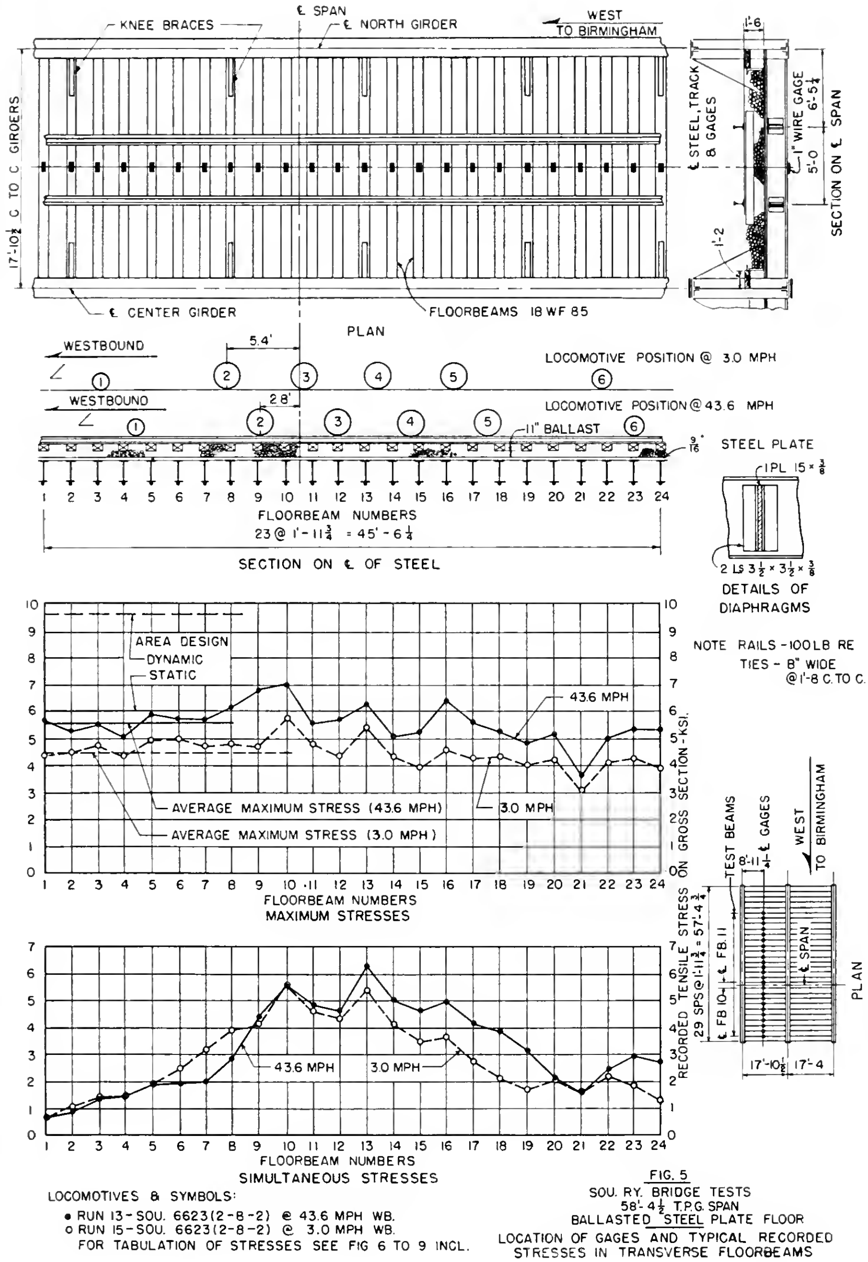


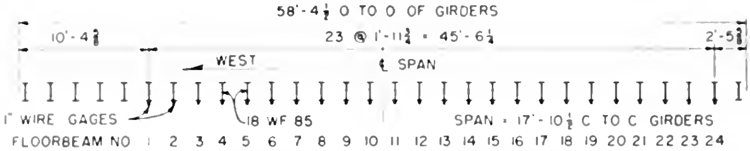
FIG. 5
SOU. RY. BRIDGE TESTS
58'-4½ T.P.G. SPAN
BALLASTED STEEL PLATE FLOOR
LOCATION OF GAGES AND TYPICAL RECORDED STRESSES IN TRANSVERSE FLOORBEAMS

FIG 6

SOUTHERN RAILWAY BRIDGE TESTS

58'-4½ THROUGH GIRDER SPAN - BALLASTED CORTEN PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ BETWEEN GIRDERS

TEST TRAIN	WESTBOUND LOCOMOTIVE TYPE 2-8-2 SOU 6623																	
RUN NO	15			14			8			9			7			16		
SPEED IN MPH	80			31			40			41			46			80		
LOCOMOT POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT 6.5' WEST OF ℄ SPAN			6 3' WEST OF ℄ SPAN			6 7' WEST OF ℄ SPAN			6 5' WEST OF ℄ SPAN			1 4' WEST OF ℄ SPAN			6.5' WEST OF ℄ SPAN		
COL NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO
1	4 40	0 70	0 98	4 55	0 90	1 00	4 45	0 85	0 96	4 40	0 75	0 96	4 10	0 30	0 94	4 55	0 75	0 99
2	4 50	1 05	1 00	4 65	1 20	1 03	4 65	1 10	1 00	4 70	1 15	1 02	4 65	0 40	1 07	4 60	1 15	1 00
3	4 75	1 45	1 06	4 85	1 60	1 07	4 90	1 60	1 06	4 95	1 60	1.08	3 50	0 80	0 80	5 15	1 60	1 12
4	4 40	1 45	0 98	4 40	1 55	0 97	4 30	1 50	0 93	4 35	1 50	0 97	4 45	1 00	1 02	4 40	1 55	0 96
5	4 95	1 95	1 10	5 10	2 25	1 12	5 05	2 25	1 09	5 05	2 10	1 10	3 60	1 40	0 83	5 10	2 15	1 11
6	5 00	2 50	1 12	5 05	2 85	1 11	5 10	2 75	1 10	5 10	2 75	1 11	3 60	1 50	0 83	5 05	2 75	1 10
7	4 70	3 20	1 05	4 80	3 50	1 06	4 70	3 55	1 01	4 80	3 50	1 05	4 85	1 75	1 12	4 70	3 50	1 03
8	4 80	3 90	1 07	4 80	4 10	1 06	4 80	4 10	1 03	4 80	4 00	1 05	4 95	2 35	1 14	4 75	4 05	1 04
9	4 70	4 15	1 05	4 95	4 70	1 09	5 00	4 50	1 08	4 90	4 40	1 07	3 55	3 05	0 82	5 20	4 70	1 14
10	5 80	5 55	1 29	5 90	5 70	1 30	5 90	5 60	1 27	5 85	5 60	1 27	5 90	4 95	1 36	5 90	5 70	1 29
11	4 80	4 60	1 07	4 70	4 60	1 04	4 70	4 50	1 01	4 70	4 45	1 02	4 70	4 30	1 08	4 80	4 55	1 05
12	4 35	4 35	0 97	4 45	4 45	0 98	4 50	4 50	0 97	4 70	4 70	1 02	4 75	4 75	1 09	4 45	4 30	0 97
13	5 40	5 40	1 21	5 05	5 05	1 11	5 10	5 10	1 10	5.00	5 00	1 09	5 20	5 20	1 20	5 45	5 45	1 19
14	4 35	4 10	0 97	4 45	4 10	0 98	4 55	4 25	0 98	4 50	4 25	0 98	4 60	4 50	1 06	4 40	4 15	0 96
15	3 95	3 50	0 88	4 05	3 55	0 89	4 10	3 60	0 88	4 00	3 60	0 87	4 10	4 10	0.94	4 05	3 60	0 88
16	4 60	3 60	1 03	4 80	3 50	1 06	4 70	3 60	1.01	4 60	3 55	1 00	4 65	4 55	1 07	4 65	3 70	1 02
17	4 25	2 70	0 95	4 35	2 40	0 96	4 40	2 60	0 95	4 30	2 55	0 94	4 30	4 00	0 99	4 25	2 65	0 93
18	4 35	2 10	0 97	4 40	1 95	0 97	4 50	2 05	0 97	4 40	2 00	0 96	4 50	3 95	1 03	4 30	2 05	0 94
19	4 00	1 70	0 89	4 20	1 85	0 93	4 20	1 90	0 91	4 10	1 80	0 89	4 15	3 00	0 95	4 05	1 75	0 88
20	4 20	2 05	0 94	4 15	2 25	0 91	4 40	2 30	0 95	4 30	2 20	0 94	4 35	2 15	1 00	4 30	2 20	0 94
21	3 10	1 65	0 69	3 00	1 80	0 66							3 20	1 35	0 74	3 20	1 80	0 70
22	4 10	2 15	0 91	4 10	2 00	0 90	4 15	2 20	0.89	4 00	2 10	0 87	4 10	2 00	0 94	4 15	2 20	0 91
23	4 20	1 85	0 94	4 25	1 60	0 94	4 40	1 80	0 95	4 20	1 70	0 92	4 35	2 15	1 00	4 35	1 80	0 95
24	3 90	1 30	0 87	3 95	1 25	0 87	4 20	1 45	0 91	4 00	1 30	0 87	4 20	2 85	0 97	4 00	1 30	0 87
AVERAGE	4 48			4 54			4 64			4.59			4 35			4 58		
STATIC*	6 00			6 00			6 00			6 00			6 00			6 00		
DYNAMIC*	9 56			9 56			9 56			9 56			9 56			9 56		

NOTE STRESSES SHOWN ARE TENSION VALUES IN KSI

"MAX" ARE MAXIMUM RECORDED STRESSES AT EACH FLOORBEAM

"SIMULT" - SIMULTANEOUS STRESS WITH MAXIMUM STRESS AT FLOORBEAM 13

"RATIO" OF RECORDED MAXIMUM STRESS TO AVERAGE RECORDED MAXIMUM STRESS

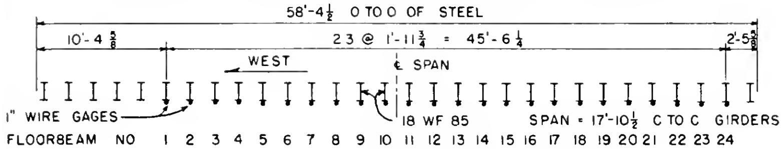
* AREA DESIGN

FIG. 7

SOUTHERN RAILWAY BRIDGE TESTS

58'-4½ THROUGH GIRDER SPAN - BALLASTED CORTEN PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



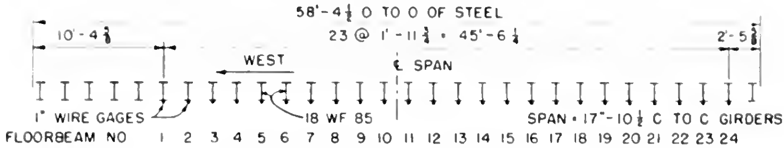
SECTION ON ℄ BETWEEN GIRDERS

TEST TRAIN	WESTBOUND																	
	LOCOMOTIVE TYPE 2-8-2															2AX DIESEL		
	SOU 4905			SOU 6623												SOU 4117		
RUN NO	3			10			11			12			13			19		
SPEED IN MPH	194			330			390			395			436			42		
LOCOMOT. POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT															FIRST AXLE AT		
	91' WEST OF ℄ SPAN			59' WEST OF ℄ SPAN			1.7' WEST OF ℄ SPAN			1.2' WEST OF ℄ SPAN			28' WEST OF ℄ SPAN			31.9 WEST OF ℄ SPAN		
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO.	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
1	325	080	070	5.85	100	1.11	560	0.05	105	555	005	102	565	065	102	355	170	111
2	510	160	110	500	125	095	520	040	097	525	015	097	525	090	095	325	095	102
3	510	180	110	5.10	180	097	540	0.70	1.01	555	0.30	102	550	1.35	099	340	070	107
4	4.90	1.90	1.05	470	1.70	0.89	500	0.90	0.94	5.00	0.50	0.92	5.10	1.50	0.92	2.90	045	091
5	535	280	1.15	570	200	1.08	550	150	103	565	100	104	590	190	107	325	080	102
6	540	350	116	595	240	113	570	160	107	570	140	105	570	195	103	320	120	100
7	500	405	107	5.70	295	108	575	190	108	555	150	102	570	200	103	305	190	095
8	485	445	104	580	390	1.10	620	260	116	600	225	1.11	6.15	2.80	111	3.30	290	104
9	545	525	117	625	520	1.19	650	450	122	705	400	130	685	440	124	325	310	102
10	580	565	124	655	585	124	680	525	127	695	480	128	700	5.50	127	365	305	114
11	480	435	103	510	485	097	535	460	100	545	450	101	555	480	100	3.45	215	108
12				5.15	490	0.98	5.15	490	0.96	535	480	099	5.70	465	103	3.25	3.05	102
13	435	435	093	575	5.75	1.09	6.10	6.10	114	6.00	6.00	111	6.25	6.25	1.13	4.35	435	136
14	450	4.05	0.97	4.80	450	0.91	495	495	0.93	5.00	490	092	5.05	5.00	091	3.25	300	102
15	3.90	2.90	084	470	375	0.89	495	480	0.93	5.00	3.70	0.92	525	4.65	095	2.75	2.35	086
16	4.70	2.55	1.01	5.40	400	1.02	5.70	5.40	1.07	6.05	5.40	1.12	6.40	4.95	1.16	3.20	2.85	1.00
17	4.30	1.85	0.92	4.80	3.10	0.91	5.20	4.85	0.97	5.45	4.85	1.01	5.60	4.15	1.01	3.00	2.95	0.94
18	4.45	2.00	0.95	4.75	2.40	0.90	5.20	4.70	0.97	520	4.90	0.97	5.25	3.85	0.95	3.20	2.95	1.00
19	4.50	2.50	0.97	4.65	2.05	0.88	5.00	3.90	0.94	5.05	4.35	0.93	4.85	3.10	0.88	2.75	2.25	0.86
20	4.60	2.75	0.99	4.90	2.15	0.93	5.35	2.75	1.00	5.60	3.40	1.03	5.15	2.10	0.93	3.05	2.35	0.95
21	4.10	2.05	0.88				2.35	0.80	0.44	2.85	1.35	0.53	3.60	1.55	0.65	2.80	2.35	0.88
22	4.20	1.50	0.90	4.70	2.30	0.89	4.50	1.85	0.84	4.45	2.30	0.82	5.00	2.40	0.90	2.85	2.65	0.89
23	420	1.30	0.90	4.85	2.15	0.92	5.40	2.35	1.01	5.10	2.65	0.94	5.30	2.90	0.96	2.95	2.15	0.92
24	4.35	1.60	0.93	4.95	1.60	0.94	5.30	2.55	0.99	5.15	3.00	0.95	5.30	2.70	0.96	2.90	1.25	0.91
AVERAGE	4.66			5.27			5.34			5.42			5.54			3.19		
STATIC	6.00			6.00			6.00			6.00			6.00			3.80		
DYNAMIC	9.56			9.56			9.56			9.56			9.56			5.30		

FOR NOTES SEE FIG 6.

FIG 8
SOUTHERN RAILWAY BRIDGE TESTS
58'-4½ THROUGH GIRDER SPAN — BALLASTED CORTEN PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



SECTION ON ℄ BETWEEN GIRDERS

TEST TRAIN	WESTBOUND																	
	LOCOMOTIVE TYPE: 2-AXLE DIESEL																	
	SOU. 4117						SOU. 6806			SOU. 6705			SOU. 6712			FRT CAR		
RUN NO	20			18			17			5 *			2					
SPEED IN MPH	5.2			6.0			6.1			25.1			29.7					
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST AXLE AT																	
	31.8' WEST OF ℄ SPAN			31.9' WEST OF ℄ SPAN			35.5' WEST OF ℄ SPAN			34.8' WEST OF ℄ SPAN			32.5' WEST OF ℄ SPAN					
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO.	MAX	SIMULT	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX.	SIMULT	RATIO	MAX.	SIMULT	RATIO
1	3.75	1.75	1.18	3.85	1.80	1.21	3.33	1.00	1.19	3.25	0.50	1.03	3.55	1.20	1.17	3.00		1.46
2	3.20	1.00	1.00	3.15	0.90	0.99	2.85	0.40	1.02	3.10	0.45	0.98	2.65	0.50	0.87	2.05		1.00
3	3.35	0.70	1.05	3.35	0.75	1.06	2.95	0.30	1.06	3.45	0.55	1.10	3.05	0.40	1.01	2.25		1.10
4	3.00	0.50	0.94	3.10	0.55	0.98	2.65	0.40	0.95	2.85	0.50	0.90	2.85	0.40	0.94	2.20		1.07
5	3.30	0.75	1.03	3.25	0.80	1.02	3.00	0.60	1.07	3.25	1.05	1.03	3.10	0.50	1.02	2.20		1.07
6	3.30	1.25	1.03	3.30	1.20	1.04	2.85	0.95	1.02	3.25	1.60	1.03	2.95	0.75	0.97	1.90		0.93
7	3.20	1.90	1.00	3.10	1.90	0.98	2.75	1.50	0.99	3.05	2.35	0.97	2.60	1.20	0.86	2.05		1.00
8	3.35	2.85	1.05	3.35	2.85	1.06	2.90	2.45	1.04	3.20	3.20	1.02	2.65	2.00	0.87	2.15		1.05
9	3.05	2.70	0.96	3.25	2.95	1.02	2.50	2.50	0.90	3.10	2.95	0.98	4.15	3.25	1.37	1.55		0.76
10	3.60	3.00	1.13	3.65	2.95	1.15	3.20	2.80	1.15	4.45	3.40	1.41	3.90	2.50	1.29	1.95		0.95
11	3.50	3.15	1.10	3.40	2.65	1.07	2.90	2.35	1.04	3.50	2.95	1.11	3.15	2.30	1.04	2.05		1.00
12	3.35	3.05	1.05	3.35	3.10	1.06	2.95	2.70	1.06	3.20	3.20	1.02	2.60	2.35	0.86	1.65		0.81
13	4.35	4.35	1.36	4.15	4.15	1.30	2.90	2.90	1.04	2.65	2.40	1.16	3.90	3.90	1.29	2.75		1.35
14	3.10	2.80	0.97	3.25	2.95	1.02	2.85	2.55	1.02	3.10	2.40	0.98	3.05	2.65	1.01	2.15		1.05
15	2.85	2.40	0.89	2.75	2.35	0.86	2.35	1.70	0.84	2.15	1.85	0.68	2.70	1.90	0.89	1.85		0.90
16	3.10	2.70	0.97	3.15	2.80	0.99	2.90	1.70	1.04	3.35	2.15	1.06	3.15	2.10	1.04	2.35		1.15
17	3.00	2.90	0.94	3.00	2.90	0.94	2.70	1.90	0.97	2.90	2.50	0.92	2.65	1.90	0.87	2.15		1.05
18	3.15	2.95	0.99	3.10	2.80	0.98	2.80	2.40	1.00	3.10	3.00	0.98	2.90	2.25	0.96	2.25		1.10
19	2.75	2.25	0.81	2.55	2.20	0.80	2.45	2.45	0.88	3.15	2.70	1.00	2.90	2.25	0.96	1.45		0.71
20	3.05	2.40	0.96	3.00	2.35	0.94	2.80	2.45	1.00	3.60	2.60	1.14	3.10	1.85	1.02	2.20		1.07
21	2.65	2.30	0.83	2.65	2.25	0.83	2.40	2.00	0.86	2.00	1.45	0.64	2.40	1.40	0.79	1.45		0.71
22	2.85	2.60	0.89	2.75	2.60	0.86	2.65	2.40	0.95	2.95	2.85	0.94	2.55	2.10	0.84	1.75		0.85
23	2.95	2.20	0.92	2.90	2.10	0.91	2.80	2.75	1.00	3.45	3.00	1.10	3.25	2.30	1.07	2.00		0.98
24	2.90	1.35	0.91	2.90	1.30	0.91	2.60	2.25	0.93	3.45	2.40	1.10	2.90	2.25	0.96	1.80		0.88
AVERAGE	3.19			3.18			2.79			3.15			3.03			2.05		
STATIC	3.80			3.80			3.76			3.76			3.76					
DYNAMIC	5.30			5.30			5.25			5.25			5.25					

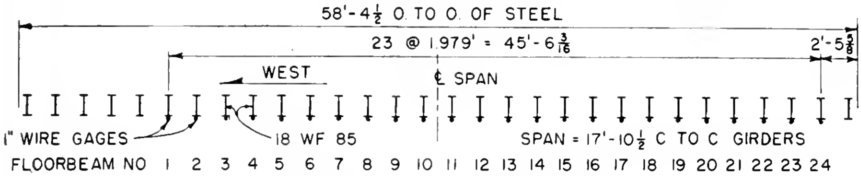
NOTE: * SIMULTANEOUS FOR RUN NO. 5 AT FLOORBEAM 12
FOR OTHER NOTES SEE FIG 6

FIG. 9

SOUTHERN RAILWAY BRIDGE TESTS

58'-4½ THROUGH GIRDER SPAN - BALLASTED CORTEN PLATE FLOOR

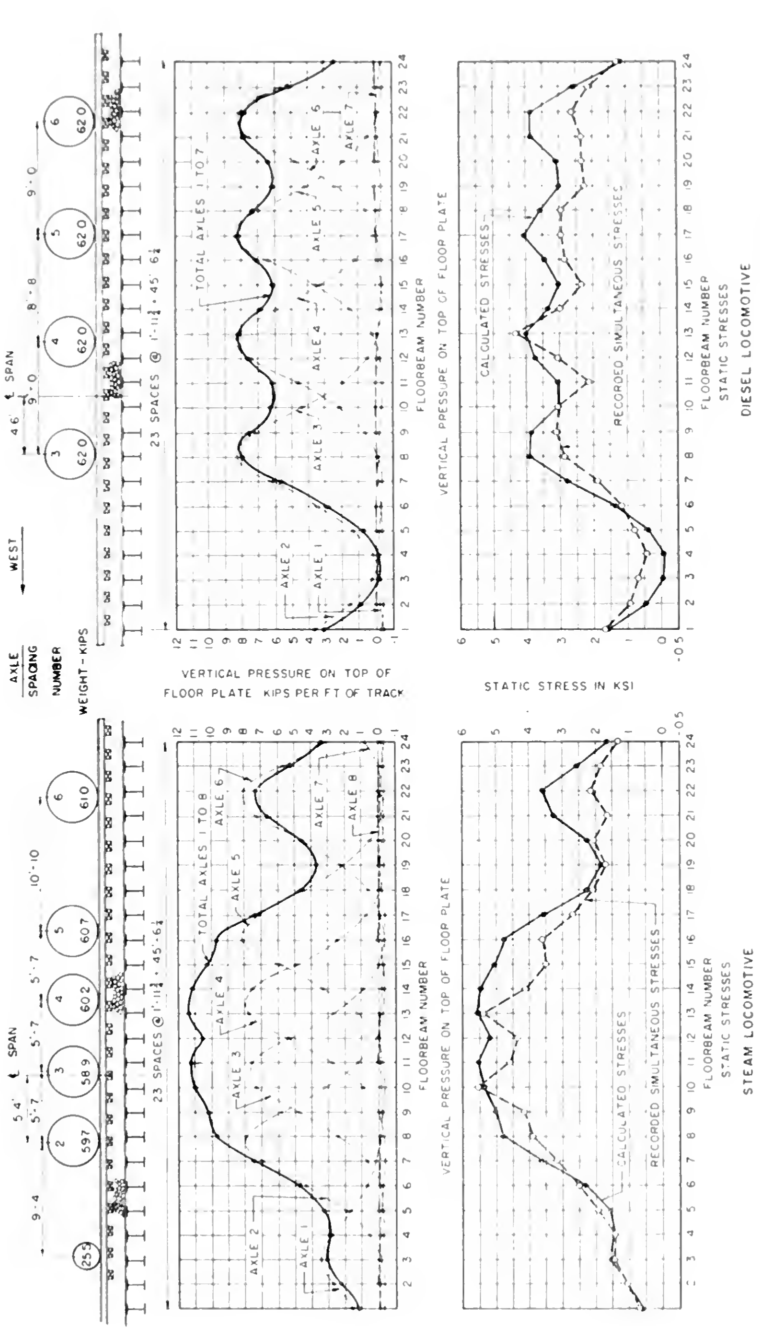
RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



SECTION ON ℄ BETWEEN GIRDERS

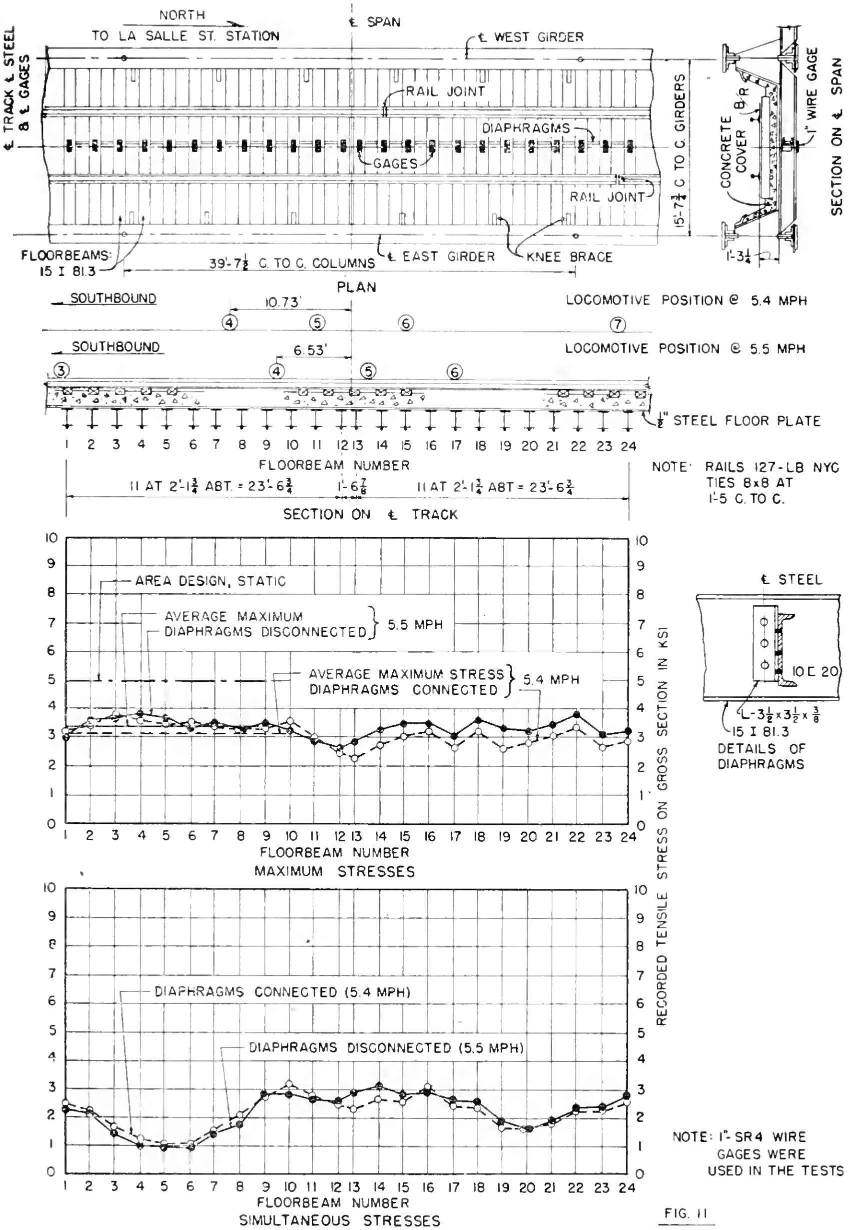
TEST TRAIN	WESTBOUND														
	LOCOMOTIVE TYPE: 2-AXLE DIESEL														
	SOU. 4117									SOU 4132			SOU. 4130		
RUN NO.	21			22			23			4			1		
SPEED IN MPH	35.4			36.9			40.1			46.2			59.4		
LOCOMOT. POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT														
	30.0' WEST OF ℄ SPAN			32.3' WEST OF ℄ SPAN			29.9' WEST OF ℄ SPAN			33.5' WEST OF ℄ SPAN			45.6' WEST OF ℄ SPAN		
COL. NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
FLOOR-BEAM NO.	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
1	4.40	2.40	1.28	4.35	0.90	1.28	4.30	2.20	1.26	2.95	0.55	0.87	3.85	1.35	1.12
2	3.30	1.55	0.96	3.30	0.45	0.97	3.30	1.25	0.96	3.35	0.40	0.98	3.35	2.15	0.97
3	3.50	1.05	1.02	3.45	0.50	1.01	3.50	0.75	1.02	3.45	0.40	1.01	4.85	3.75	1.41
4	3.05	0.55	0.89	3.15	0.45	0.93	3.80	0.50	1.11	3.00	0.35	0.88	3.15	2.25	0.91
5	3.55	0.75	1.04	3.55	0.85	1.04	3.40	0.75	0.99	3.40	0.80	1.00	3.10	2.25	0.90
6	3.45	0.80	1.01	3.30	1.45	0.97	3.30	1.10	0.96	3.30	1.30	0.97	3.10	2.40	0.90
7	3.05	1.25	0.89	3.15	2.20	0.93	3.15	1.45	0.92	3.15	1.90	0.93	3.05	2.60	0.89
8	3.40	2.30	0.99	3.55	3.20	1.04	3.50	2.10	1.02	3.30	2.90	0.97	3.35	2.65	0.97
9	4.20	4.10	1.23	3.55	3.20	1.04	3.90	3.10	1.14	4.15	4.05	1.22	5.10	3.45	1.48
10	3.90	3.65	1.14	4.00	3.50	1.18	4.00	3.20	1.17	4.75	4.00	1.40	3.35	1.85	0.97
11	3.50	3.00	1.02	3.60	3.00	1.06	3.55	2.40	1.04	3.75	2.90	1.10	3.25	2.18	0.94
12	3.30	3.15	0.96	3.40	3.40	1.00	3.40	2.60	0.99	3.45	3.15	1.01	3.20	2.90	0.93
13	4.55	4.55	1.33	4.80	4.80	1.41	4.60	4.60	1.34	3.75	3.75	1.10	4.40	4.40	1.28
14	3.30	3.30	0.96	3.35	2.85	0.99	3.30	3.30	0.96	3.20	3.00	0.94	3.25	3.25	0.94
15	3.10	2.45	0.90	2.95	2.25	0.87	2.75	2.60	0.80	2.65	1.90	0.78	3.00	2.75	0.87
16	3.20	2.45	0.93	3.30	2.75	0.97	3.15	2.70	0.92	3.30	1.85	0.97	3.20	2.60	0.93
17	3.05	2.50	0.89	3.05	2.75	0.90	2.95	2.70	0.86	3.15	1.80	0.93	3.00	2.55	0.87
18	3.40	2.85	0.99	3.20	2.55	0.94	3.20	3.10	0.94	3.40	2.50	1.00	3.50	3.00	1.02
19	3.10	2.40	0.90	3.00	2.00	0.88	2.95	2.55	0.86	3.45	2.90	1.01	3.55	2.35	1.03
20	3.50	2.25	1.02	3.45	2.15	1.01	3.50	2.50	1.02	3.65	2.80	1.07	3.80	1.10	1.10
21	3.10	1.95	0.90	2.85	2.00	0.81	3.05	2.00	0.89	3.20	2.40	0.94	3.20	0.40	0.93
22	3.00	2.50	0.88	3.00	2.10	0.88	3.05	2.30	0.89	3.05	2.90	0.90	2.65	0.10	0.77
23	3.25	2.60	0.95	3.20	1.60	0.94	3.25	2.50	0.95	3.55	3.40	1.04	3.10	0	0.90
24	3.05	1.85	0.89	3.10	0.85	0.91	3.15	1.85	0.92	3.30	3.20	0.97	3.10	0.25	0.90
AVERAGE	3.43			3.40			3.42			3.40			3.44		
STATIC	3.80			3.80			3.80			3.76			3.76		
DYNAMIC	5.30			5.30			5.30			5.25			5.25		

FOR NOTES SEE FIG. 6.



NOTE
STEAM LOCOMOTIVE - SOU RY 6623 (SEE FIG 6 RUN 15) - 30 MPH
DIESEL LOCOMOTIVE - SOU RY 4117 (SEE FIG 7 - RUN 19) - 42 MPH
RAILS 100 LB RE, $I = 490\ IN^4$
ASSUMED TRACK MODULUS u = 1500 LB PER IN OF RAIL LENGTH PER IN DEPRESSION

FIG 10
SOUTHERN RAILWAY BRIDGE TESTS
58'-4½ T P G SPAN - BALLASTED STEEL PLATE FLOOR
COMPARISON OF RECORDED AND CALCULATED STATIC STRESSES
STRESSES IN TRANSVERSE FLOORBEAMS



LOCOMOTIVES & SYMBOLS
○ RUN 4 - NYC 4202 & 4302 (3 AX DIESELS) AT 5.4 MPH
DIAPHRAGMS CONNECTED
● RUN 14 - NYC 4201 & 4301 (3 AX. DIESELS) AT 5.5 MPH
DIAPHRAGMS DISCONNECTED
FOR TABULATION OF STRESSES SEE FIGS. 12 & 13.

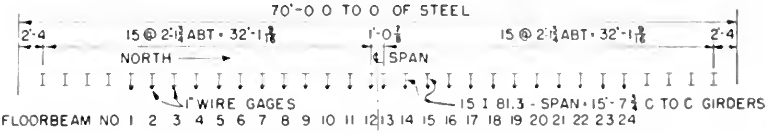
FIG. 11
N.Y.C.R.R. BRIDGE TESTS
70'-0 T.P.G. SPAN - TRACK NO.1
CONCRETE AND STEEL PLATE FLOOR
LOCATION OF GAGES AND
TYPICAL RECORDED STRESSES
IN TRANSVERSE FLOORBEAMS

FIG 12

NEW YORK CENTRAL RAILROAD BRIDGE TESTS – TRACK NO.1

70'-0 THROUGH GIRDER SPAN – CONCRETE AND STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ OF TEST TRACK

DIAPHRAGMS CONNECTED																					
TEST TRAIN	3-AXLE DIESELS NO 4202 & 4302 - SOUTHBOUND																				
RUN NO.	4			6			5			7			3			1			2		
SPEED IN MPH	5.4			6.5			6.6			7.5			7.6			8.5			10.1		
LOCOMOT POSITION FOR SIMULTAN STRESS	FIRST WHEEL AT 44.9' SOUTH OF ℄ SPAN			41.9' SOUTH OF ℄ SPAN			42.4' SOUTH OF ℄ SPAN			41.4' SOUTH OF ℄ SPAN			38.3' SOUTH OF ℄ SPAN			40.7' SOUTH OF ℄ SPAN			40.7' SOUTH OF ℄ SPAN		
COL. NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
FLOOR-BEAM NO.	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX.	SIMULT	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
1	3.20	2.45	1.03	3.05	2.25	0.98	3.00	2.20	0.98	3.10	2.30	1.00	3.30	2.40	1.04						
2	3.40	2.25	1.09	3.35	2.10	1.08	3.30	2.00	1.08	3.35	2.10	1.08	3.50	2.15	1.10						
3	3.80	1.70	1.22	3.75	1.60	1.21	3.75	1.55	1.23	3.75	1.60	1.21	3.90	1.65	1.23						
4	3.60	1.25	1.15	3.40	1.00	1.09	3.45	1.00	1.13	3.45	1.05	1.12	3.60	1.20	1.13						
5	3.45	1.10	1.11	3.30	1.00	1.06	3.30	0.95	1.08	3.30	0.95	1.07	3.50	1.10	1.10						
6	3.50	1.10	1.12	3.35	1.00	1.08	3.35	1.00	1.10	3.35	1.05	1.08	3.50	1.20	1.10						
7	3.40	1.55	1.09	3.30	1.40	1.06	3.30	1.40	1.08	3.20	1.40	1.04	3.35	1.50	1.05						
8	3.25	2.10	1.04	3.25	2.00	1.04	3.15	1.95	1.03	3.15	2.00	1.02	3.05	2.00	0.96						
9	3.30	2.70	1.06	3.05	2.55	0.98	3.15	2.60	1.03	3.05	2.60	0.99	3.20	2.65	1.01						
10	3.60	3.20	1.15	3.40	3.05	1.09	3.40	2.95	1.11	3.25	2.90	1.05	3.35	2.95	1.05						
11	3.00	2.80	0.96	2.85	2.65	0.92	2.85	2.55	0.93	2.80	2.65	0.91	2.90	2.65	0.91						
12	2.45	2.45	0.79	2.25	2.25	0.72	2.35	2.30	0.77	2.15	2.15	0.70	2.30	2.30	0.72						
13	2.30	2.30	0.74	2.40	2.40	0.77	2.30	2.30	0.75	2.35	2.35	0.76	2.50	2.50	0.79	2.50	2.50	0.83	2.55	2.55	0.84
14	2.75	2.60	0.88	2.75	2.65	0.88	2.75	2.55	0.90	2.70	2.70	0.87	2.80	2.80	0.88	2.80	2.65	0.93	2.75	2.70	0.91
15	3.05	2.55	0.98	3.15	2.70	1.01	3.05	2.60	1.00	3.25	2.75	1.05	3.20	2.85	1.01	3.40	3.00	1.13	3.20	3.10	1.06
16	3.25	3.05	1.04	3.40	3.20	1.09	3.35	3.10	1.10	3.35	3.20	1.08	3.45	3.40	1.08	3.40	3.25	1.13	3.35	3.30	1.11
17	2.70	2.40	0.87	2.75	2.45	0.88	2.70	2.45	0.88	2.75	2.45	0.89	2.85	2.60	0.90	2.65	2.50	0.88	2.75	2.55	0.91
18	3.25	2.35	1.04	3.30	2.35	1.06	3.20	2.30	1.05	3.25	2.35	1.05	3.35	2.45	1.05	3.20	2.30	1.06	3.25	2.30	1.07
19	2.65	1.65	0.85	2.80	1.65	0.90	2.75	1.70	0.90	2.80	1.75	0.91	2.90	1.80	0.91	2.80	1.70	0.93	2.85	1.70	0.94
20	2.85	1.65	0.91	2.95	1.70	0.95	2.85	1.65	0.93	2.95	1.75	0.95	3.00	1.95	0.94	2.85	1.70	0.95	3.00	1.75	0.99
21	3.05	1.80	0.98	3.25	1.90	1.04	3.15	1.85	1.03	3.25	2.05	1.05	3.20	2.00	1.01	3.15	2.00	1.05	3.20	2.10	1.06
22	3.35	2.25	1.07	3.55	2.35	1.14	3.40	2.25	1.11	3.55	2.40	1.15	3.65	2.60	1.15	3.50	2.60	1.16	3.50	2.60	1.16
23	2.70	2.25	0.87	3.00	2.30	0.96	2.85	2.30	0.93	2.95	2.35	0.95	3.00	2.60	0.94	2.90	2.40	0.96	2.90	2.50	0.96
24	2.90	2.50	0.93	3.00	2.60	0.96	2.85	2.55	0.93	3.05	2.70	0.99	3.00	2.85	0.94	3.00	2.70	1.00	3.10	2.85	1.02
AVERAGE	3.12			3.11			3.06			3.09			3.18			3.01			3.03		
STATIC *	4.98																				

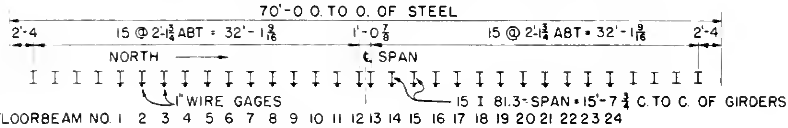
NOTE: STRESSES SHOWN ARE TENSION VALUES IN KSI.
"MAX" ARE MAXIMUM RECORDED STRESSES AT EACH FLOORBEAM
"SIMULT."- SIMULTANEOUS STRESSES WITH MAXIMUM STRESS AT FLOORBEAM 13.
"RATIO" OF RECORDED MAXIMUM STRESS TO AVERAGE RECORDED MAXIMUM STRESS.
* AREA DESIGN FOR BEAMS OTHER THAN FLOORBEAM 12 AND 13.

FIG. 13

NEW YORK CENTRAL RAILROAD BRIDGE TESTS - TRACK NO. 1

70'-0 THROUGH GIRDER SPAN - CONCRETE AND STEEL PLATE FLOOR

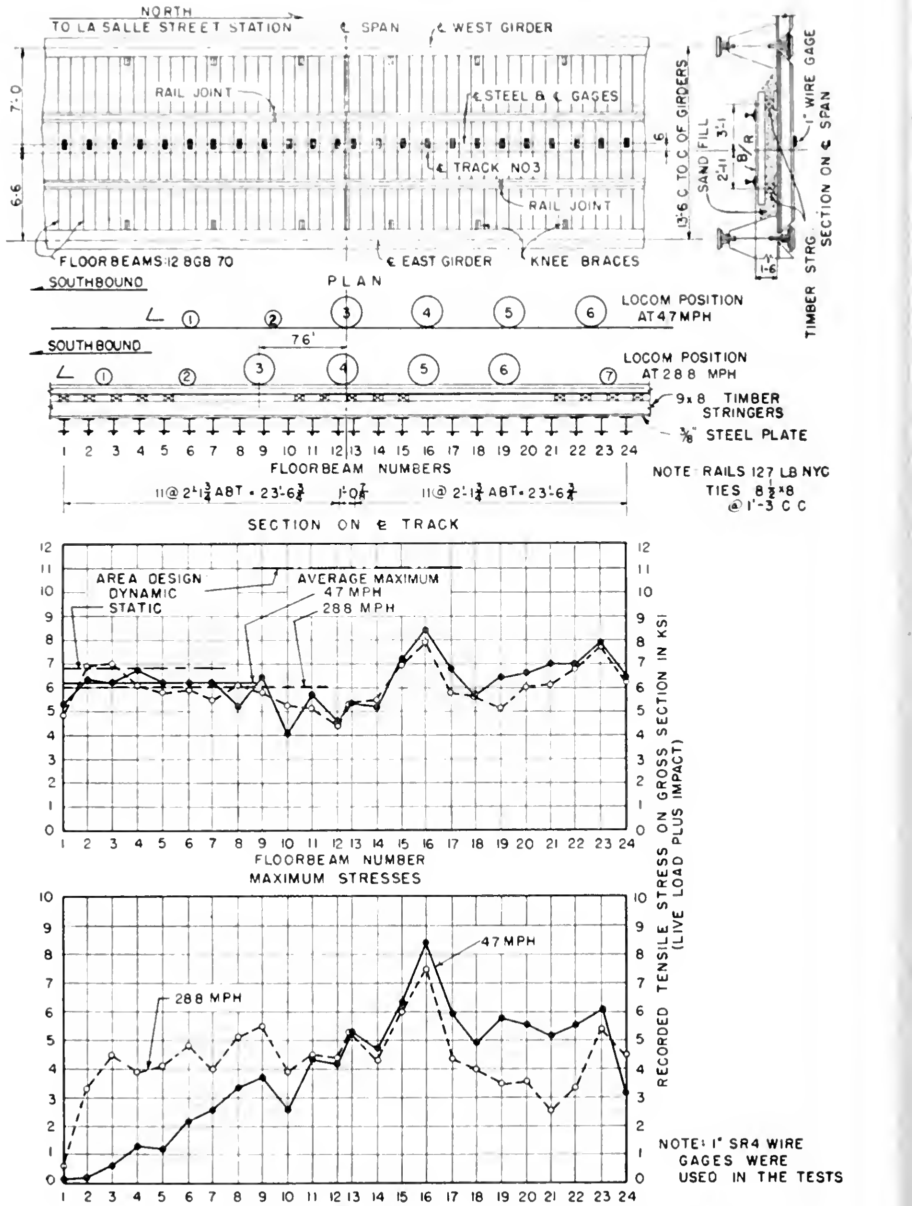
RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ OF TEST TRACK

DIAPHRAGMS DISCONNECTED																					
TEST TRAIN	3-AXLE DIESELS: NO. 4201 & 4301 - SOUTHBOUND																				
RUN NO.	9			10			13			14			11			12			8		
SPEED IN MPH	4.2			4.6			4.7			5.5			5.7			5.7			6.0		
LOCOMOT POSITION FOR SIMULTAN STRESS	FIRST WHEEL AT																				
	39.1' SOUTH OF ℄ SPAN			34.2' SOUTH OF ℄ SPAN			39.6' SOUTH OF ℄ SPAN			40.7' SOUTH OF ℄ SPAN			40.0' SOUTH OF ℄ SPAN			46.4' SOUTH OF ℄ SPAN			44.7' SOUTH OF ℄ SPAN		
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
FLOOR-BEAM NO.	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
1	2.95	2.30	0.88	2.95	2.30	0.90	2.90	2.25	0.90	3.05	2.30	0.91	2.95	2.25	0.89	3.00	2.30	0.88	2.85	2.20	0.84
2	3.50	2.20	1.04	3.50	2.15	1.07	3.60	2.25	1.11	3.55	2.20	1.06	3.50	2.15	1.05	3.60	2.25	1.06	3.55	2.25	1.05
3	3.80	1.55	1.13	3.65	1.55	1.11	3.70	1.55	1.14	3.70	1.45	1.11	3.70	1.50	1.11	3.75	1.55	1.10	3.75	1.50	1.11
4	3.85	1.05	1.15	3.85	1.05	1.17	3.85	1.05	1.19	3.85	1.00	1.15	3.85	1.05	1.16	3.95	1.15	1.16	3.85	1.05	1.13
5	3.60	0.95	1.07	3.55	0.95	1.08	3.60	1.00	1.11	3.65	1.00	1.09	3.60	1.00	1.08	3.65	1.10	1.07	3.60	0.95	1.06
6	3.30	0.95	0.98	3.30	0.95	1.01	3.35	1.00	1.03	3.35	0.95	1.00	3.35	0.95	1.01	3.45	1.05	1.01	3.35	0.95	0.99
7	3.25	1.25	0.97	3.25	1.30	0.99	3.30	1.40	1.02	3.45	1.45	1.03	3.25	1.35	0.98	3.40	1.45	1.00	3.25	1.30	0.96
8	3.30	1.95	0.98	3.15	1.90	0.96	3.10	1.95	0.96	3.25	1.75	0.97	3.20	1.85	0.96	3.25	2.05	0.95	3.20	2.00	0.94
9	3.50	2.80	1.04	3.50	2.75	1.07	3.55	2.85	1.10	3.50	2.80	1.04	3.55	2.75	1.07	3.60	2.95	1.06	3.45	2.75	1.02
10	3.25	2.95	0.97	3.25	2.90	0.99	3.35	3.00	1.03	3.25	2.85	0.97	3.30	2.85	0.99	3.40	3.05	1.00	3.15	2.85	0.93
11	2.90	2.70	0.86	2.90	2.65	0.88	3.05	2.75	0.94	2.95	2.70	0.88	2.90	2.65	0.87	3.00	2.75	0.88	2.90	2.60	0.86
12	2.60	2.60	0.77	2.55	2.55	0.78	2.60	2.60	0.80	2.65	2.55	0.79	2.55	2.55	0.77	2.70	2.70	0.79	2.60	2.45	0.77
13	2.90	2.90	0.86	2.95	2.95	0.90	2.85	2.85	0.88	2.90	2.90	0.87	2.95	2.95	0.89	2.85	2.85	0.84	2.95	2.95	0.87
14	3.30	3.05	0.98	3.30	3.00	1.01	3.15	2.95	0.97	3.30	3.10	0.99	3.25	3.05	0.98	3.25	3.10	0.95	3.35	3.20	0.99
15	3.50	2.90	1.04	3.40	2.75	1.04	3.35	2.70	1.03	3.55	2.85	1.06	3.40	2.80	1.02	3.55	2.90	1.04	3.50	2.90	1.03
16	3.50	3.15	1.04	3.55	3.20	1.08	3.00	2.60	0.93	3.50	3.00	1.04	3.50	3.10	1.05	3.50	2.90	1.03	3.45	3.20	1.02
17				3.05	2.60	0.93	2.95	2.50	0.91	3.05	2.65	0.91	3.05	2.65	0.92	3.10	2.75	0.91			
18	3.65	2.60	1.09	3.65	2.60	1.11	3.55	2.50	1.09	3.65	2.60	1.09	3.60	2.55	1.08	3.75	2.70	1.10	3.85	2.70	1.13
19	3.35	1.90	1.00	3.20	1.90	0.98	3.15	1.85	0.97	3.35	1.90	1.00	3.30	1.85	0.99	3.55	2.05	1.04	3.40	1.90	1.00
20	3.25	1.70	0.97	3.05	1.60	0.93	3.00	1.60	0.93	3.25	1.65	0.97	3.25	1.70	0.98	3.25	1.70	0.95	3.50	1.75	1.03
21	3.70	2.00	1.10	3.40	1.90	1.04	3.20	1.80	0.99	3.50	1.85	1.04	3.50	1.90	1.05	3.60	2.00	1.06	3.65	1.95	1.08
22	3.85	2.25	1.15	3.65	2.30	1.11	3.55	2.15	1.09	3.85	2.35	1.15	3.85	2.40	1.16	4.00	2.45	1.17	4.10	2.50	1.21
23	3.20	2.30	0.95	3.00	2.30	0.91	2.90	2.10	0.90	3.15	2.30	0.94	3.10	2.35	0.93	3.30	2.45	0.97	3.25	2.40	0.96
24	3.25	2.70	0.97	3.15	2.65	0.96	3.10	2.60	0.96	3.25	2.75	0.97	3.35	2.80	1.01	3.45	2.85	1.01	3.45	2.90	1.02
AVERAGE	3.36			3.28			3.24			3.35			3.33			3.41			3.39		
STATIC *	4.98																				

FOR NOTES SEE FIG 12.



LOCOMOTIVES & SYMBOLS
- • RUN 29 - NYC 6020 (4-8-4) @ 47 MPH SB
- ○ RUN 8 - NYC 6021 (4-8-4) @ 28.8 MPH SB

FOR TABULATION OF STRESSES, SEE FIGS. 15 TO 18 INCL.

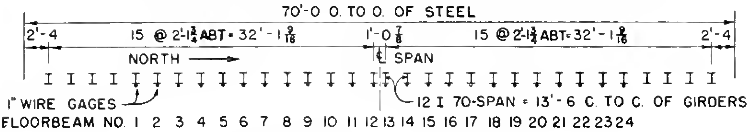
FIG 14

NY.C.R.R BRIDGE TESTS
70'-0 TPG SPAN TRACK NO.3
TIMBER STRINGERS-STEEL PLATE FLOOR

LOCATION OF GAGES AND TYPICAL RECORDED STRESSES IN TRANSVERSE FLOORBEAMS

FIG. 15
NEW YORK CENTRAL RAILROAD BRIDGE TESTS - TRACK NO. 3
70'-0 THROUGH GIRDER SPAN - TIMBER STRINGERS STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ OF TEST TRACK

TEST TRAIN	SOUTHBOUND															NORTHBOUND					
	LOCOMOTIVE TYPE: 3 - AXLE DIESELS																				
	NYC 4030			NYC 4201			NYC 4001			NYC 4021			NYC 4018			RI 635			NYC 4009		
RUN NO.	1			5			21			13			12			24			27		
SPEED IN MPH	17.7			18.8			24.1			34.2			36.4			27.2			29.0		
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST WHEEL AT																				
	51.0' SOUTH OF ℄ SPAN			40.9' SOUTH OF ℄ SPAN			77.2' SOUTH OF ℄ SPAN			75.5' SOUTH OF ℄ SPAN			38.5' SOUTH OF ℄ SPAN			78.0' NORTH OF ℄ SPAN			50.5' NORTH OF ℄ SPAN		
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
FLOOR-BEAM NO.	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
1	3.50	0.10	0.76	2.60	1.00	0.65	3.00	1.90	0.67	3.30	2.30	0.72	3.30	2.00	0.75	3.50	0.10	0.80	3.60	2.00	0.77
2	4.50	0.30	0.97	4.20	1.10	1.05	4.60	3.50	1.03	4.90	3.80	1.70	3.80	3.70	0.86	4.50	0	1.03	4.80	3.40	1.02
3	5.60	0.30	1.21	5.10	1.30	1.27	5.50	4.40	1.23	5.70	4.50	1.24	5.30	4.60	1.20	4.70	0.10	1.07	4.80	3.60	1.02
4	4.60	0.30	1.00	4.00	0.80	1.00	4.60	3.00	1.03	4.60	3.40	1.00	4.70	3.20	1.06	4.90	0.20	1.12	5.10	2.40	1.09
5	5.50	0.40	1.19	4.00	0.50	1.00	4.70	1.50	1.05	4.70	2.20	1.02	4.80	2.00	1.09	4.50	0.30	1.03	4.90	1.40	1.04
6	4.80	0.80	1.04	4.10	0.90	1.02	4.60	1.20	1.03	4.70	1.20	1.02	4.90	1.60	1.11	4.60	0.80	1.05	4.80	1.20	1.02
7	4.40	1.10	0.95	3.70	1.30	0.92	4.30	1.30	0.96	4.40	1.30	0.96	4.50	1.40	1.02	4.80	1.30	1.09	4.70	1.60	1.00
8	6.60	4.60	1.43	4.30	3.60	1.07	5.10	2.90	1.14	5.10	2.30	1.11	5.00	2.50	1.13	5.30	3.80	1.21	4.60	3.10	0.98
9	5.10	4.50	1.10	4.50	4.20	1.12	5.10	4.30	1.14	5.10	3.80	1.11	5.10	4.10	1.15	5.00	4.70	1.14	5.30	4.20	1.13
10	3.60	3.00	0.78	3.60	2.60	0.90	4.00	3.10	0.90	4.30	4.00	0.94	4.10	3.50	0.93	3.50	2.80	0.80	3.60	2.40	0.77
11	3.80	3.30	0.82	3.50	2.90	0.87	4.10	3.30	0.92	4.40	4.20	0.96	4.30	3.40	0.97	4.30	3.70	0.98	4.60	3.50	0.98
12	3.80	3.60	0.82	2.80	2.50	0.70	3.50	3.20	0.79	3.50	3.20	0.76	3.40	3.10	0.77	3.40	3.10	0.78	3.70	3.60	0.79
13	4.70	4.70	1.02	3.50	3.50	0.87	4.00	4.00	0.90	4.20	4.20	0.91	3.90	3.90	0.88	3.80	3.80	0.87	4.40	4.40	0.94
14	4.40	3.40	0.95	3.50	3.00	0.87	3.50	3.20	0.79	4.10	3.90	0.89	3.80	3.60	0.86	3.50	3.00	0.80			
15	5.50	4.40	1.19	5.10	4.10	1.27	5.70	4.80	1.28	5.90	5.10	1.28	5.60	4.90	1.27	5.30	4.30	1.21	5.70	5.10	1.21
16	6.60	5.60	1.43	6.00	5.20	1.50	6.70	5.70	1.40	6.80	5.80	1.48	6.50	4.70	1.47	6.20	5.30	1.41	6.50	4.70	1.38
17	4.10	2.40	0.89	3.70	2.60	0.92	4.40	2.40	0.99	4.40	2.90	0.96	4.20	2.90	0.95	4.10	2.40	0.93	4.70	2.30	1.00
18	3.40	1.30	0.74	3.20	1.40	0.80	3.60	1.20	0.81	3.70	1.30	0.81	3.50	1.20	0.79	3.20	1.40	0.73	3.60	1.10	0.77
19	4.20	1.30	0.91	3.50	1.20	0.87	3.10	0.60	0.70	3.40	0.80	0.74	3.20	0.70	0.72	3.80	1.30	0.87	4.30	0.70	0.92
20	4.90	1.80	1.06	4.40	1.40	1.10	4.60	0.40	1.03	4.50	0.50	0.98	4.20	0.50	0.95	4.60	1.80	1.05	4.90	0.40	1.04
21	4.50	2.80	0.97	3.90	1.60	0.97	4.30	0.20	0.96	3.90	0.30	0.85	3.50	0.20	0.79	4.30	2.30	0.98	4.80	0.20	1.02
22	4.30	3.70	0.93	4.20	2.70	1.05	4.40	0.10	0.99	4.60	0	1.00	4.40	0	1.00	4.30	3.30	0.98	4.60	0	0.98
23				5.00	4.40	1.25	5.30	0.10	1.19	5.60	0	1.22	5.70	0	1.29	5.20	4.40	1.19	5.40	0	1.15
24	3.90	3.10	0.84	3.90	3.10	0.97	4.30	0	0.96	4.40	0.10	0.96	4.40	0.10	1.00	4.10	3.20	0.93	4.50	0	0.96
AVERAGE	4.62			4.01			4.46			4.59			4.42			4.39			4.69		
STATIC *	5.20			4.61			5.20			5.20			5.20			5.02			5.20		
DYNAMIC *	7.32			6.49			7.32			7.32			7.32			7.06			7.32		

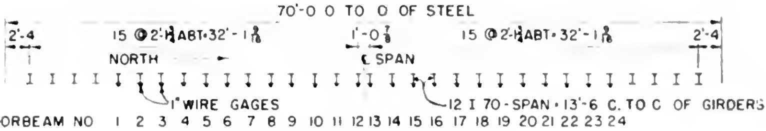
NOTE: STRESSES SHOWN ARE TENSION VALUES IN KSI.
"MAX." ARE MAXIMUM RECORDED STRESSES AT EACH FLOORBEAM
"SIMULT." - SIMULTANEOUS STRESSES WITH MAXIMUM STRESS AT FLOORBEAM 13.
"RATIO" OF RECORDED MAXIMUM STRESS TO AVERAGE RECORDED MAXIMUM STRESS.
*AREA DESIGN FOR BEAMS OTHER THAN FLOORBEAMS 12 AND 13.

FIG 16

NEW YORK CENTRAL RAILROAD BRIDGE TESTS - TRACK NO 3

70'-0 THROUGH GIRDER SPAN - TIMBER STRINGERS STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ OF TEST TRACK

TEST TRAIN	NORTHBOUND						SOUTHBOUND														
	3-AXLE DIESELS						LOCOMOTIVE TYPE: 4-8-4												0-8-0		
	NYC 4028			NYC 3202			NYC 6020			TENDER			NYC 6021			TENDER			NYC 7576		
RUN NO.	10			23			29						8						25		
SPEED IN MPH	44.6			45.9			47						28.8						18.8		
LOCOMOT. POSITION	FIRST WHEEL AT						FIRST DRIVER AT														
FOR SIMULTAN. STRESS	52.0' NORTH OF ℄ SPAN			99.4' NORTH OF ℄ SPAN			AT ℄ OF SPAN			82.1' SOUTH OF ℄ SPAN			7.6' SOUTH OF ℄ SPAN			77.0' SOUTH OF ℄ SPAN			6.8' SOUTH OF ℄ SPAN		
COL NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
FLOOR-BEAM NO.	MAX	SIMULT	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT	RATIO
1	4.40	3.00	0.86	3.80	1.60	0.85	5.30	0.10	0.85	4.60	2.80	0.75	4.90	0.60	0.82	4.10	2.40	0.64	4.70	0.40	0.80
2	5.30	4.30	1.03	4.50	3.30	1.00	6.30	0.20	1.01	6.20	4.30	1.01	6.90	3.30	1.15	6.70	5.60	1.04	6.30	0.20	1.07
3	5.70	4.60	1.11	5.10	3.90	1.14	6.20	0.60	1.00	6.00	5.10	0.98	7.00	4.50	1.16	7.40	6.80	1.15	6.10	0.20	1.03
4	4.90	4.70	0.96	4.80	2.80	1.07	6.70	1.30	1.08	6.80	5.60	1.11	6.10	3.90	1.01	6.70	5.80	1.04	6.70	0.40	1.13
5	6.60	2.60	1.29	4.40	1.40	0.98	6.20	1.20	1.00	6.30	5.20	1.03	5.80	4.10	0.97	6.70	6.00	1.04	6.10	0.30	1.03
6	5.60	1.90	1.09	4.60	1.20	1.03	6.20	2.20	1.00	6.30	5.70	1.03	5.90	4.80	0.98	6.70	5.70	1.04	6.20	0.80	1.05
7	4.60	1.30	0.90	4.60	1.30	1.03	6.20	2.60	1.00	6.20	5.40	1.01	5.50	4.00	0.92	6.20	5.10	0.96	5.80	1.20	0.98
8	5.80	2.40	1.13	5.00	2.70	1.12	5.20	3.30	0.84	5.70	5.10	0.93	6.10	5.10	1.01	6.90	5.90	1.07	6.30	3.00	1.06
9	6.40	4.10	1.25	4.90	3.90	1.09	6.40	3.70	1.03	6.40	5.60	1.04	5.80	5.50	0.97	7.20	6.10	1.12	6.10	4.50	1.03
10	4.10	3.70	0.80	3.60	2.20	0.80	4.10	2.60	0.66	4.40	3.90	0.72	5.30	3.90	0.88	5.70	5.30	0.89	4.40	3.60	0.75
11	4.30	4.20	0.84	4.60	3.00	1.03	5.70	4.30	0.92	5.50	5.00	0.90	5.10	4.50	0.85	5.70	5.40	0.89	5.90	5.30	1.00
12	3.90	3.90	0.76	3.40	2.60	0.76	4.60	4.20	0.74	4.40	4.20	0.72	4.40	4.40	0.73	4.90	4.80	0.76	4.80	4.70	0.81
13	5.40	5.40	1.05	4.00	4.00	0.89	5.30	5.30	0.85	5.40	5.40	0.88	5.30	5.30	0.88	6.20	6.20	0.96	6.00	6.00	1.02
14	5.90	5.90	1.15	3.50	3.20	0.78	5.20	4.70	0.84	5.40	5.20	0.88	5.50	4.30	0.92	5.90	5.50	0.92	4.90	4.80	0.83
15	5.70	5.60	1.11	5.60	4.30	1.25	7.20	6.30	1.16	7.70	6.50	1.26	7.00	6.00	1.16	7.70	6.50	1.20	7.30	6.90	1.24
16	6.70	6.10	1.31	6.20	5.10	1.38	8.40	8.40	1.35	8.70	5.80	1.42	7.90	7.50	1.31	8.50	5.20	1.32	7.90	6.90	1.34
17	4.10	3.20	0.80	4.30	2.80	0.96	6.80	5.90	1.09	6.80	1.90	1.11	5.80	4.40	0.97	6.10	1.50	0.95	5.80	4.10	0.98
18	5.60	1.80	1.09	3.60	1.40	0.80	5.80	4.90	0.93	5.60	1.10	0.91	5.70	4.00	0.95	5.90	0.90	0.92	4.70	1.90	0.80
19	3.50	1.00	0.68	4.00	1.30	0.89	6.40	5.80	1.03	5.80	0.60	0.95	5.10	3.50	0.85	5.20	0.30	0.81	5.20	1.40	0.88
20	4.40	0.80	0.86	4.60	1.10	1.03	6.60	5.60	1.06	6.00	0.30	0.98	6.00	3.60	1.00	6.10	0.10	0.95	5.70	1.10	0.97
21	4.00	0.40	0.78	4.50	1.10	1.00	7.00	5.20	1.12	6.30	0.20	1.03	6.10	2.60	1.01	5.80	0	0.90	6.20	0.80	1.05
22	6.20	0.30	1.21	4.40	1.40	0.98	7.00	5.60	1.12	6.40	0.10	1.04	6.80	3.40	1.13	7.10	0	1.00	6.30	0.80	1.06
23	5.50	0.10	1.07	5.20	3.60	1.16	7.90	6.10	1.27	7.80	0.40	1.27	7.80	5.40	1.30	7.90	-0.10	1.23	6.80	1.20	1.15
24	4.20	0	0.82	4.20	3.70	0.94	6.40	3.20	1.03	6.40	0	1.04	6.30	4.50	1.05	6.80	-0.20	1.06	5.80	1.30	0.98
AVERAGE	5.12			4.48			6.22			6.13			6.01			6.43			5.91		
STATIC	5.20			4.94			6.84			6.58			6.84			6.58			6.94		
DYNAMIC	7.32			6.94			11.00			9.25			11.00			9.25			11.15		

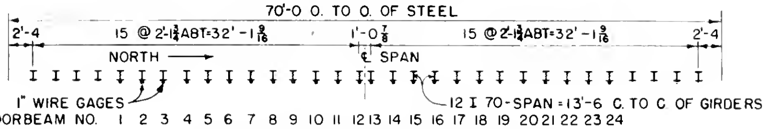
NOTE. – INDICATES COMPRESSION
FOR OTHER NOTES SEE FIG 15

FIG. 17

NEW YORK CENTRAL RAILROAD BRIDGE TESTS – TRACK NO. 3

70'-0 THROUGH GIRDER SPAN – TIMBER STRINGERS STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ OF TEST TRACK

TEST TRAIN	SOUTHBOUND									NORTHBOUND												
	0-8-0			LOCOMOTIVE TYPE: 4-6-4																		
	NYC 7387			NYC 5410			TENDER			NYC 5235			TENDER			NYC 5442			NYC 5321			
RUN NO.	19			14						9						7			18			
SPEED IN MPH	23.6			14.1						23.7						40.1			42.0			
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST DRIVER AT																					
	8.0' SOUTH OF ℄ SPAN			11.9' SOUTH OF ℄ SPAN			82.7' SOUTH OF ℄ SPAN			1.1' NORTH OF ℄ SPAN			43.7' SOUTH OF ℄ SPAN			6.6' NORTH OF ℄ SPAN			5.4' NORTH OF ℄ SPAN			
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
FLOOR-BEAM NO.	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	
1	4.40	0.50	0.76	4.10	0	0.67	4.20	2.30	0.68	4.00	0.10	0.75	3.70	2.20	0.67	5.90	1.00	0.90	4.70	1.20	0.74	
2	6.80	0.80	1.18	5.70	0.10	0.93	6.20	4.90	1.00	5.50	0.40	1.03	6.00	4.40	1.08	7.50	4.80	1.14	7.10	4.80	1.12	
3	7.00	1.20	1.21	6.70	0.20	1.10	7.30	6.30	1.18	6.10	0.60	1.14	7.00	5.10	1.26	8.10	5.90	1.24	7.80	5.70	1.23	
4	6.20	1.00	1.07	5.60	0.60	0.92	6.10	5.30	0.99	5.70	1.10	1.06	6.00	4.40	1.08	6.70	4.50	1.02	6.30	4.80	1.00	
5	6.10	0.90	1.06	5.90	0.70	0.97	6.50	5.80	1.05	5.50	1.20	1.03	6.00	3.90	1.08	6.90	4.00	1.05	6.20	4.50	0.98	
6	5.90	1.40	1.02	5.60	1.40	0.92	6.20	5.80	1.00	5.30	2.10	0.99	5.80	2.80	1.05	6.50	4.10	0.99	6.20	4.10	0.98	
7	5.60	2.70	0.97	5.40	1.80	0.88	5.80	5.40	0.94	4.80	2.10	0.90	5.20	1.50	0.94	5.30	3.20	0.81	5.30	3.30	0.84	
8	6.40	5.60	1.11	5.50	2.90	0.90	6.30	5.70	1.02	5.20	3.10	0.97	6.30	1.90	1.14	6.30	4.70	0.96	5.30	5.00	0.84	
9	6.70	5.90	1.16	5.90	3.30	0.97	6.60	5.90	1.07	5.50	3.30	1.03	6.30	2.60	1.14	6.70	5.90	1.02	5.70	5.40	0.90	
10	4.90	4.30	0.85	4.60	2.50	0.75	5.00	4.30	0.81	4.50	2.90	0.84	4.70	1.70	0.85	5.30	4.10	0.81	4.50	3.70	0.71	
11	5.60	4.10	0.97	5.20	4.00	0.85	5.60	5.10	0.91	4.80	3.90	0.90	5.00	4.20	0.90	6.10	4.50	0.93	4.80	4.10	0.76	
12	4.60	4.20	0.80	4.60	4.20	0.75	4.70	4.70	0.76	4.00	3.90	0.75	4.50	4.10	0.81	4.80	4.10	0.73	5.20	4.80	0.82	
13	5.50	5.50	0.95	6.00	6.00	0.98	5.80	5.80	0.94	4.90	4.90	0.92	5.10	5.10	0.92	6.10	6.10	0.93	5.60	5.60	0.89	
14	4.30	4.30	0.75	5.80	5.30	0.95	5.60	5.20	0.91	4.90	4.40	0.92	5.10	4.80	0.92	5.70	5.00	0.87	5.20	4.90	0.82	
15	7.00	6.50	1.21	7.70	2.90	1.26	7.70	6.50	1.25	6.70	5.30	1.25	6.70	5.80	1.21	7.80	6.20	1.19	7.40	6.40	1.17	
16	7.80	6.30	1.35	9.00	2.70	1.47	8.70	5.20	1.41	8.00	6.80	1.49	7.60	4.90	1.37	8.90	8.00	1.36	8.60	8.20	1.36	
17	5.40	2.80	0.94	6.40	1.40	1.05	6.10	1.40	0.99	5.60	4.50	1.04	5.30	1.70	0.96	5.30	4.30	0.81	5.90	5.30	0.93	
18	5.20	1.30	0.90	5.80	4.20	0.95	5.50	0.90	0.89	4.80	3.40	0.90	4.90	1.00	0.89	5.60	3.00	0.86	5.20	3.30	0.82	
19	3.60	0.60	0.62	5.60	4.20	0.92	4.90	0.40	0.79	4.40	3.10	0.82	4.00	0.80	0.72	5.70	2.00	0.87	8.10	1.90	1.28	
20	5.80	0.70	1.01	6.60	5.20	1.08	6.10	0.10	0.99	5.20	4.30	0.97	5.00	1.60	0.90	6.70	2.30	1.02	6.90	2.90	1.09	
21	5.60	0.60	0.97	6.70	4.30	1.10	6.10	0	0.99	5.00	3.20	0.93	5.00	2.40	0.90	6.80	1.70	1.04	7.00	2.30	1.11	
22	5.70	0.90	0.99	7.30	3.80	1.19	6.90	0	1.12	5.80	3.40	1.08	6.10	4.30	1.10	7.40	1.80	1.13	7.50	2.10	1.19	
23	6.90	2.00	1.20	8.30	5.10	1.36	7.90	0	1.28	6.70	4.90	1.25	6.50	6.30	1.17	8.00	1.80	1.22	8.40	1.80	1.33	
24	5.40	1.90	0.94	6.40	3.50	1.05	6.40	0	1.04	5.50	3.80	1.03	5.20	5.10	0.94	7.10	0.60	1.08	6.80	0.50	1.08	
AVERAGE	5.77			6.11			6.18			5.36			5.54			6.55			6.32			
STATIC *	6.94			6.44			6.58			6.20			6.21			6.44			6.20			
DYNAMIC *	11.15			10.36			9.25			9.95			8.75			10.36			9.95			

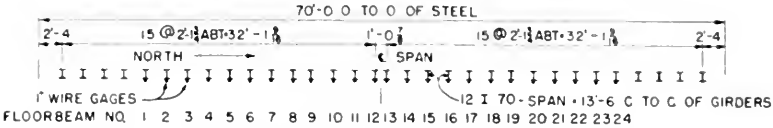
FOR NOTES SEE FIG. 15

FIG 18

NEW YORK CENTRAL RAILROAD BRIDGE TESTS - TRACK NO 3

70'-0 THROUGH GIRDER SPAN - TIMBER STRINGERS STEEL PLATE FLOOR

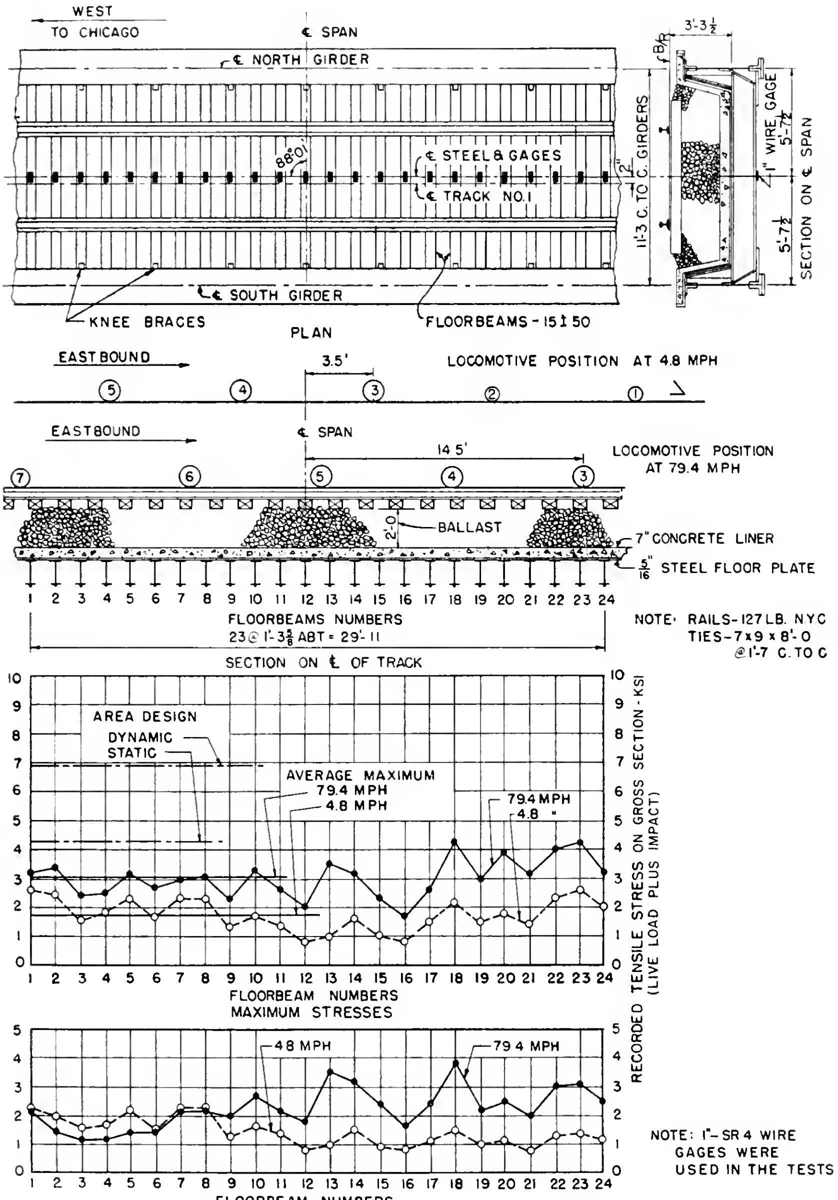
RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ OF TEST TRACK

TEST TRAIN	NORTHBOUND															SOUTHBOUND								
	LOCOMOTIVE TYPE: 4 - 6 - 2																							
	NYC 4441			NYC 4856			RI 890			RI 928			RI 922			NYC 4596			NYC 4491			NYC 4596		
RUN NO.	11			15			16			26			22			6			28			20		
SPEED IN MPH	16.8			28.8			42.6			489			596			199			22.4			26.2		
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST DRIVER AT																							
	AT ℄ OF SPAN			1.7' NORTH OF ℄ SPAN			1.7' NORTH OF ℄ SPAN			9.7' NORTH OF ℄ SPAN			9.1' NORTH OF ℄ SPAN			0.4' NORTH OF ℄ SPAN			0.3' SOUTH OF ℄ SPAN			5.8' SOUTH OF ℄ SPAN		
COL NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
FLOOR-BEAM NO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX.	SIMULT	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT	RATIO	MAX.	SIMULT.	RATIO
1	3.50	0.10	069	380	070	073	380	100	074	370	090	064	340	060	0 55	3 20	0	060	390	0	0.76	3.30	0.20	0.59
2	5.30	0.30	1.04	6.20	2.00	1.20	5.60	3.20	1.09	6.20	1.50	1.07	5.70	1.60	0.92	5.30	0.20	0.99	5.00	0 20	0.98	5.90	0.70	1.06
3	6 20	060	1.22	6.50	3 60	126	6.40	4.20	1.25	5.80	1.70	1.00	690	1.90	1.11	640	0.40	1.19	5 20	0.20	1.02	6.70	1.50	1.20
4	5.10	0.80	1.00	540	3.60	1.04	540	2.90	105	6.70	1.90	1.16	6.50	3 40	1.05	5.50	0.70	1 03	560	070	1.09	5.80	1.90	104
5	5.30	0 90	1.04	5.50	2.80	1.06	4.80	2.20	0.94	6 20	1.90	1.07	6.30	3 70	1.02	5.90	0 70	1.10	5.00	0 80	0 98	6 60	2 40	1.18
6	5 20	160	1.02	5.30	2 20	1.02	4 90	2 90	0 96	5 30	2 30	0 92	5.20	2.90	084	5 50	1 20	103	5 30	140	1.04	580	2.50	1.04
7	4 50	1.70	088	460	1 70	089	470	400	0.92	5 70	2 20	0.99	480	2 40	077	480	120	0 90	500	180	098	500	2.50	0.90
8	520	2 50	1.02	540	3.00	1.04	5 50	5.00	1.07	460	2.90	0.80	5.90	3 80	0.95	5.20	2.20	0.97	4 80	2.80	0.94	5.50	4.00	0.99
9	5 40	3 10	1.06	5 20	420	100	5.80	5 40	1.13	5 30	3.70	0.92	7 10	5 90	1.15	5.00	2.80	0.93	5.00	3.20	0 98	5.40	4.90	0.97
10	460	2.70	0 90	4 20	2.90	0 81	4 30	4 20	0.84	4 20	3 40	0.73	5 90	4 40	0 95	4 10	2.80	0 77	340	2 40	0.66	4.00	3.90	0.72
11	4 50	3.80	0.88	4.40	3.70	0.85	4 80	4 80	0.94	5.30	5.10	0.92	6 20	4 80	1.00	460	4 00	0.86	4 60	4.10	0.90	5.10	4.50	0.92
12	3.80	3.80	0.75	4 40	4.30	0.85	3.80	3.70	0 74	4 40	4 30	0 76	5 80	5.00	0.94	4.10	4.10	0.77	4 20	3 80	0.82	4.20	3.80	0.75
13	4 60	4.60	0.90	4.70	4 70	0.91	4 80	4 80	0.94	6 00	6 00	1.04	7 80	7 80	1 26	5 20	5.20	0.97	4 80	4 80	0.94	5.50	5.50	0.99
14	4 50	4.10	0.88	4.60	3.90	089	4 40	3.80	0.86	5 30	5.10	0.92	6.20	6.20	1.00	5.10	4 80	0.95	4 20	4.10	0.82	5.10	5.10	0.92
15	6 50	6.10	1.27	6.60	5.70	1.27	6 50	4.20	1 27	6.90	6.10	1.19	7 80	6.50	1 26	7 00	6.50	1.31	6 40	6 00	1.25	7.00	6.00	1 26
16	7 60	7.00	1.49	7 20	7.10	1.39	7 40	4 00	1.44	8.20	6 20	1 4 2	7 60	7 40	1 23	7 90	7.80	1 47	7 00	6 80	1.37	7.80	6 40	1.40
17	5.00	4.00	0 98	4.30	3 60	0.83	4 60	1.40	0.90	5.60	3.90	0 97	5.00	4 10	0 81	5.20	4 50	0.97	5 40	4 60	1 06	5.20	3 40	0 93
18	4 40	3.30	0.86	4.10	2.30	0 79	4.50	1.00	0.88	4.80	2 20	0 83	4 50	2 00	0.73	4 50	3 50	0.84	4 30	3.90	0 84	4 40	2.00	0.79
19	4.20	2 60	0.82	3.90	1.70	0.75	4 40	0 80	0.86	4.80	2.10	0.83	4 40	1 30	0.71	4.20	2.80	0.78	4.50	3 60	0.88	4.00	1.60	0.72
20	5.10	2.70	1 00	5.00	1.90	0.96	5.60	0 80	1.09	5.90	2 10	1.02	6 50	1 60	1 05	5.50	3.00	1 03	5 60	3.30	1.09	6.10	2.70	1.10
21	4 70	1.90	0 92	5 50	1.50	1.06	5.10	0.50	1.00	6 80	1 50	1 18	6 80	1 10	1.10	5.40	2.00	1 01	6.10	2.50	1.19	6.00	2.80	1.08
22	5 50	2.40	1.08	5 60	1 20	1 08	5.10	0 30	1 00	6 70	1 40	1 16	8 40	1.00	1 36	6 40	2 30	1 19	5.40	2 90	1.06	6 60	2 20	1.18
23	6 50	3 40	1 27	6.50	1.00	1 26	5 90	0.10	1 15	8 10	1.40	1.40	7 90	0 90	1 27	7 10	3 40	1 32	6 70	3 90	1.31	7.00	2 10	1 26
24	5 20	1 70	1 02	5 20	0 40	1 00	4 80	0	0.94	6 20	0.40	1.07	6.00	0 40	0 97	5 50	1 80	1.03	5 40	1.90	1.06	5 60	0 90	1.01
AVERAGE	5.10			5 18			5 12			5 78			6.20			5 36			5.12			5.57		
STATIC *	6.35			5.74			5.26			5.26			5.26			6.35			6.35			6.35		
DYNAMIC*	10.20			9.23			8.46			8.46			8.46			10.20			10.20			10.20		

FOR NOTES SEE FIG 15



LOCOMOTIVES & SYMBOLS:
- • RUN 2 — NYC 6021 (4-8-4) @ 79.4 MPH E.B.
- o RUN 12 — NYC 6011 (4-8-4) @ 4.8 MPH E.B.

FOR TABULATION OF STRESSES SEE FIGS. 20 TO 24 INCL.

FIG. 19

N.Y.C.R.R. BRIDGE - TESTS
39'-0¼ GIRDER SPAN
BALLASTED CONCRETE AND STEEL FLOOR PLATE

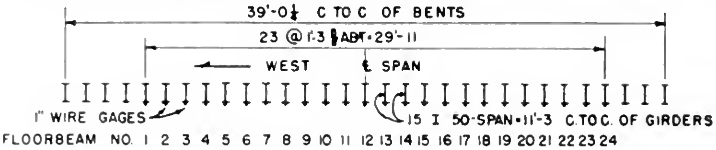
LOCATION OF GAGES AND TYPICAL RECORDED STRESSES IN TRANSVERSE FLOORBEAMS

FIG 20

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

39-0½ THROUGH GIRDER SPAN - BALLASTED CONCRETE LINED STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ OF TEST TRACK

TEST TRAIN	EASTBOUND																	
	2-AXLE DIESEL			3-AXLE DIESEL LOCOMOTIVES														
	NYC 3501			NYC 4009			NYC 4202			NYC 4029			NYC 4005			NYC 4023		
RUN NO	5			19			14			11			7			21		
SPEED IN MPH	68.7			61			69			47.7			65.5			70.4		
LOCOMOT POSITION FOR SIMULTAN STRESS	FIRST WHEEL AT																	
	101.2' EAST OF ℄ SPAN			80.9' EAST OF ℄ SPAN			73.7' EAST OF ℄ SPAN			80.3' EAST OF ℄ SPAN			78.2' EAST OF ℄ SPAN			80.1' EAST OF ℄ SPAN		
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO.	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
1	2.20	1.70	1.20	1.90	0.10	1.34	1.90	0.40	1.57	2.20	0.40	1.49	2.60	1.10	1.29	2.20	0.30	1.20
2	2.00	1.00	1.09	1.60	0.10	1.13	1.80	0.40	1.49	1.90	0.40	1.28	2.50	1.00	1.24	2.00	0	1.09
3	1.50	0.70	0.82	1.10	0.10	0.78	1.20	0.40	0.99	1.40	0.50	0.95	2.20	1.00	1.09	1.40	0.30	0.76
4	1.50	0.60	0.82	1.10	0.10	0.78	1.00	0.40	0.83	1.40	0.60	0.95	1.90	1.00	0.94	1.40	0.40	0.76
5	2.20	0.80	1.20	1.60	0.40	1.13	1.40	0.70	1.16	1.80	0.90	1.22	2.20	1.20	1.09	1.90	0.80	1.03
6	1.80	0.60	0.98	1.10	0.40	0.78	1.10	0.50	0.91	1.80	1.20	1.22	1.90	1.00	0.94	1.50	0.80	0.82
7	2.20	1.10	1.20	1.80	1.00	1.27	1.60	1.30	1.32	1.90	1.50	1.28	2.40	1.60	1.19	2.10	1.70	1.14
8	2.20	0.80	1.20	1.60	1.10	1.13	1.50	1.30	1.24	1.70	1.20	1.15	2.00	1.30	0.99	2.30	1.90	1.25
9	1.40	0.60	0.77	1.10	0.90	0.78	1.00	0.90	0.83	1.20	1.00	0.81	1.70	1.20	0.84	1.30	1.00	0.71
10	1.80	1.00	0.98	1.40	1.20	0.99	1.30	1.20	1.07	1.40	1.30	0.95	2.30	1.90	1.14	2.00	1.80	1.09
11	1.40	1.00	0.77	1.20	1.10	0.85	0.90	0.80	0.75	1.10	1.10	0.74	1.80	1.70	0.89	1.50	1.40	0.82
12	1.00	1.00	0.55	0.70	0.70	0.49	0.60	0.60	0.50	1.00	1.00	0.68	1.20	1.20	0.59	1.00	1.00	0.54
13	1.70	1.70	0.93	1.20	1.20	0.85	0.80	0.80	0.66	0.80	0.80	0.54	1.60	1.60	0.79	1.30	1.30	0.71
14	2.20	2.20	1.20	1.50	1.50	1.06	1.20	1.20	0.99	1.20	1.20	0.81	2.20	2.20	1.09	1.90	1.90	1.03
15	1.70	1.70	0.93	0.90	0.90	0.63	0.70	0.70	0.58	0.90	0.90	0.61	1.40	1.20	0.69	1.30	1.30	0.71
16	1.10	1.10	0.60	0.80	0.80	0.56	0.60	0.60	0.50	0.70	0.70	0.47	1.20	1.00	0.59	1.30	1.20	0.71
17	1.40	0.90	0.77	1.30	1.10	0.92	1.10	1.00	0.91	1.20	1.00	0.81	1.70	1.40	0.84	1.80	1.30	0.98
18	2.30	1.10	1.26	2.10	1.60	1.48	1.40	1.30	1.16	1.90	1.40	1.28	2.70	2.00	1.34	2.70	1.80	1.47
19	1.60	0.50	0.87	2.00	1.50	1.41	1.00	0.90	0.83	1.30	1.10	0.88	1.80	0.90	0.89	2.10	1.40	1.14
20	2.30	1.00	1.26	1.70	1.30	1.20	1.40	1.10	1.16	1.60	1.20	1.08	2.20	0.70	1.09	2.30	1.30	1.25
21	1.90	0.60	1.04	1.40	0.90	0.99	0.70	0.50	0.58	1.20	0.80	0.81	1.90	0.40	0.94	2.00	0.90	1.09
22	2.40	0.90	1.31	2.10	1.20	1.48	1.60	1.00	1.32	2.00	1.00	1.35	2.40	0.40	1.19	2.50	1.00	1.36
23	2.50	0.70	1.37	1.30	0.90	0.92	1.80	0.90	1.49	2.20	1.00	1.49	2.60	0.50	1.29	2.50	0.80	1.36
24	1.70	0.50	0.93	1.60	0.70	1.13	1.40	0.60	1.16	1.70	0.80	1.15	2.10	0.50	1.04	2.00	0.70	1.09
AVERAGE	1.83			1.42			1.21			1.48			2.02			1.84		
STATIC *	2.96			3.29			2.91			3.29								
DYNAMIC *	4.17			4.63			4.10			4.63								

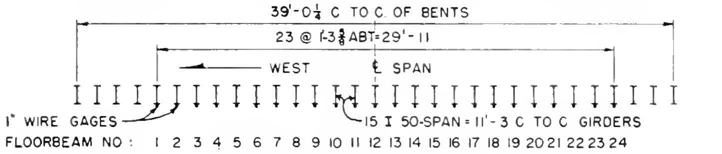
NOTE: STRESSES SHOWN ARE TENSION VALUES IN KSI.
"MAX." ARE MAXIMUM RECORDED STRESSES AT EACH FLOORBEAM.
"SIMULT."- SIMULTANEOUS STRESS WITH MAXIMUM STRESS AT FLOORBEAM 13.
"RATIO" OF RECORDED MAXIMUM STRESS TO AVERAGE RECORDED MAXIMUM STRESS.
* AREA DESIGN.

FIG. 21

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

39'-0¼ THROUGH GIRDER SPAN - BALLASTED CONCRETE LINED STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ OF TEST TRACK

TEST TRAIN	EASTBOUND																	
	3-AXLE-DEISEL LOCOMOTIVES																	
	NYC 4024			NYC 4034			NYC 4019			3-AXLE CAR			NYC 4014			NYC 4018		
RUN NO.	22*			17			26						25			3		
SPEED IN MPH	74 1			75 1			76.1						79 4			80 4		
LOCOMOT POSITION FOR SIMULTAN. STRESS	FIRST WHEEL AT																	
	79 9' EAST OF ℄ SPAN			81 0' EAST OF ℄ SPAN			83 1' EAST OF ℄ SPAN			596 3' EAST OF ℄ SPAN			79 6' EAST OF ℄ SPAN			78 4' EAST OF ℄ SPAN		
COL. NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO.	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO
1	2 40	0 30	1.26	2 50	0 20	1 26	2 40	0 20	1 33	1 80	0 90	1 44	2 20	0 50	1 24	2 40	0 50	1.30
2	2 20	0 30	1.15	2 30	0 40	1 16	2 10	0 30	1 16	1 50	0 60	1 20	2 00	0 60	1 12	2 10	0 40	1.14
3	1 70	0.30	0.89	1 70	0 10	0 85	1 40	0 30	0.77	1.00	0 50	0 80	1 50	0.40	0 84	1 70	0 60	0 92
4	1.50	0.30	0.79	1.60	0.30	0.80	1 40	0 20	0 77	0.90	0 40	0.72	1 50	0 60	0 84	1 60	0 70	0.86
5	2 00	0 80	1 05	2 00	0 50	1 00	1.90	0 50	1 05	1 40	0 60	1.12	1 90	1 30	1 07	2 00	1 00	1 08
6	1 40	0 60	0.73	1 90	0.90	0.95	1 30	0 20	0 72	1 00	0 40	0 80	1 40	1 00	0 79	1 60	1 00	0.86
7	2 10	1 40	1 10	2 30	1 30	1 16	2 10	0 80	1 16	1 50	0 80	1 20	2 10	1 80	1 18	2 10	1 50	1 14
8	2 20	1 20	1 15	2 10	1 00	1.06	2 00	0 70	1 11	1 40	0 70	1 12	1.90	1 30	1.07	2 10	1 40	1 14
9	1.30	1 10	0 68	1.40	1.10	0 70	1.20	0 60	0 66	0 90	0.40	0 72	1 10	1 10	0 62	1 30	1 20	0.70
10	1 90	1 70	1 00	2 20	2 20	1.11	1 80	1 40	1 00	1 30	1 00	1 04	1 80	1 80	1 01	1 90	1 80	1 03
11	1.60	1 40	0 84	1 50	1 30	0 75	1 50	1 20	0.83	1 10	0 80	0 88	1 50	1 50	0 84	1 60	1 40	0 86
12	1 10	1 10	0 58	1 20	1 00	0 60	1.00	1 00	0 55	0 70	0 70	0 56	1 00	1 00	0 56	1 20	1 00	0 65
13	1 50	1 30	0 79	1 60	1 60	0 80	1 50	1 50	0 83	1 10	1 10	0 88	1 70	1 70	0 96	1 50	1 50	0 81
14	1 80	1 80	0 94	2 00	2 00	1 00	1 80	1 80	1 00	1 30	1 20	1 04	1 60	1 60	0 90	1 80	1 80	0 97
15	1.40	1 30	0 73	1 50	1 50	0 75	1 30	1 20	0 72	0 90	0 80	0 72	1 20	1 20	0 68	1 20	0 90	0 65
16	1 50	1 10	0 79	1 40	1 40	0 70	1 40	1 20	0 77	0 90	0 70	0 72	1 20	1 20	0 68	0 90	0 60	0 49
17	1 80	1 30	0 94	1 80	1 50	0 90	1 80	1.70	1 00	1 20	0 70	0 96	1 60	1 30	0 90	1 70	1 00	0 92
18	2 80	1 90	1 47	2 70	2 10	1 36	2 50	2.20	1 38	1 80	1 00	1 44	2 40	1 80	1 35	2 70	1 50	1 46
19	2 30	1 30	1 20	2 50	2 10	1.26	1 70	1 30	0.94	1 10	0 50	0 88	2 10	1 40	1 18	1.70	0 90	0 92
20	2 40	1 10	1 26	2.30	1 80	1 16	2.10	1 70	1 16	1 40	0 40	1 12	2 30	1 10	1 29	2 20	0 80	1 19
21	2.00	0.70	1 05	2 10	1 60	1 06	2 10	1 40	1 16	1 20	0 30	0 96	1 80	1 00	1 01	1 80	0 60	0 97
22	2 40	0 90	1 26	2 70	2 10	1 36	2 60	1 80	1 44	1 60	0 20	1 28	2 60	0 80	1 46	2 40	0 80	1 30
23	2 60	0 50	1 36	2 50	2 00	1 26	2 50	1 80	1 38	1.70	0.10	1 36	2 50	0 80	1 40	2 70	0 90	1 46
24	2 00	0 30	1 05	2.00	1 30	1 00	2.10	1 20	1 16	1 40	0	1 12	1 90	0 60	1 07	2.10	0 90	1 14
AVERAGE	1.91			1.99			1.81			1 25			1 78			1 85		
STATIC*	3 29												3.29					
DYNAMIC*	4 63												4.63					

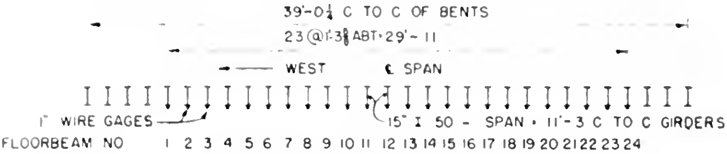
NOTE *SIMULTANEOUS READINGS FOR RUN NO 22 TAKEN AT MAXIMUM FOR FLOORBEAM 12
FOR OTHER NOTES SEE FIG. 20.

FIG 22

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

39'-0¼ THROUGH GIRDER SPAN – BALLASTED CONCRETE LINED STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ OF TEST TRACK

TEST TRAIN	EASTBOUND																	
	3-AXLE DIESELS						LOCOMOTIVE TYPE 4-8-4											
	NYC 4001			NYC 4011			NYC 6011			NYC 6021			TENDER			NYC 6005		
RUN NO	20			8			12			2						16		
SPEED IN MPH	84 1			85 4			48			79 4						81 7		
LOCOMOT POSITION FOR SIMULTAN STRESS	FIRST WHEEL AT						FIRST DRIVER AT											
	81 9' EAST OF ℄ SPAN			77 5' EAST OF ℄ SPAN			3 5' EAST OF ℄ SPAN			14 5' EAST OF ℄ SPAN			57 2' EAST OF ℄ SPAN			16 2' EAST OF ℄ SPAN		
COL NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO
1	2 20	0	1 13	2.80	0 60	1 47	2 60	2.30	1 49	3.20	2 20	1 05	3 10	2.80	1.31	3.50	3.10	1.21
2	2 10	0	1 08	2 60	0 60	1 36	2 40	2 00	1 37	3 40	1 50	1.12	2 90	2 60	1 22	3 40	2 60	1.17
3	1 70	0 10	0 87	1 80	0 80	0 94	1 60	1 60	0 92	2 40	1.20	0 79	2 40	2 00	1 01	2.80	2.10	0.97
4	1 90	0 10	0 97	1 70	0 70	0 89	1 80	1 70	1 03	2 50	1 20	0 82	2 50	2 00	1 05	2 60	1 90	0 90
5	2 20	0 10	1 13	2.10	1 20	1 10	2 30	2 20	1.31	3 20	1 40	1 05	2 90	2 40	1 22	3 30	2 40	1.14
6	1 60	0 10	0 82	1.70	0 90	0 89	1 70	1 60	0 97	2.70	1.50	0 89	2 50	2 30	1 05	3.10	2.50	1.07
7	2 20	0 50	1 13	1 90	1 50	1.00	2.30	2.30	1.31	3.00	2.20	0 98	2 80	2.70	1.18	3.10	2.40	1.07
8	2 20	0 70	1 13	2.00	1 40	1.05	2 30	2.30	1 31	3 10	2 20	1 02	2.60	2 20	1.10	3.00	2.70	1 03
9	1 20	0 70	0 62	1 60	1 10	0 84	1 40	1 30	0 80	2 30	2 00	0 76	2 00	1 90	0 84	2 00	1.70	0.69
10	1 90	1 30	0 97	2 20	1 80	1 15	1.70	1 70	0 97	3.30	2 70	1.08	2.70	2 30	1.14	2 60	2 60	0 90
11	1 50	1 40	0 77	1 30	1 30	0 68	1.40	1 40	0 80	2 60	2 20	0 85	2 10	1 70	0 89	2 20	2.10	0 76
12	1 10	1 10	0 56	1.20	0 80	0 63	0 80	0 80	0 46	2 00	1 80	0 66	1 50	1 40	0 63	1 20	1.10	0.41
13	1 60	1 60	0 82	1 40	1 40	0 73	1 00	1 00	0 57	3.50	3 50	1 15	1 60	1 60	0 68	2.00	2 00	0.69
14	1 70	1 70	.0 87	1 60	1 50	0 84	1 60	1 50	0 92	3 20	3 20	1 05	2 20	2 10	0 93	2 80	2 80	0 97
15	1 30	1 10	0 67	1 20	1 00	0 63	1.00	0 90	0.57	2 40	2 40	0.79	1 40	0.90	0 59	2 20	2.20	0 76
16	1 40	1 10	0 72	1.10	0.80	0 58	0.80	0.80	0 46	1.70	1 70	0 56	1.00	0.80	0 42	1.70	1.70	0.59
17	1 80	1 30	0 92	1 70	1 10	0 89	1.50	1 10	0 86	2 60	2 40	0 85	1 70	1 40	0 72	2.50	1.70	0.86
18	2.70	1 60	1 38	2 70	1 80	1 41	2.20	1.50	1.26	4.30	3.80	1.41	3.00	2.30	1 27	4.00	2.10	1.38
19	2 40	1 30	1 23	1.70	1.10	0 89	1.50	1 00	0 86	3 00	2.20	0 98	2 10	1 60	0 89	3.50	1.50	1.21
20	2.50	1.30	1 28	2.20	1 00	1 15	1 80	1.10	1.03	3.90	2.50	1.28	2.60	1.80	1.10	3.70	1.50	1.28
21	2 00	1 00	1 03	1 80	0 70	0 94	1 40	0 80	0 80	3 20	2 00	1 05	2.10	1 40	0 89			
22	2 60	1 20	1 33	2 50	1 00	1 31	2 30	1 30	1 31	4 00	3 00	1 31	3 10	1 90	1 31	4 00	1 80	1.38
23	2 70	1 30	1 38	2 70	1 20	1.41	2 60	1 40	1 49	4 30	3 10	1 41	3.30	2 20	1 39	4 40	2.30	1.52
24	2 30	0 90	1 18	2 30	0 80	1.20	2.00	1 10	1 14	3 30	2 50	1 08	2 70	1.50	1.14	3.20	1.80	1.10
AVERAGE	1 95			1 91			1 75			3 05			2 37			2.90		
STATIC*	3 29						4 31						4 12			4 31		
DYNAMIC*	4 63						6.93						5.84			6.93		

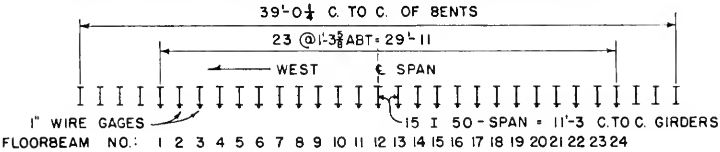
FOR NOTES SEE FIG 20.

FIG. 23

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

39'-0¼ THROUGH GIRDER SPAN – BALLASTED CONCRETE LINED STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



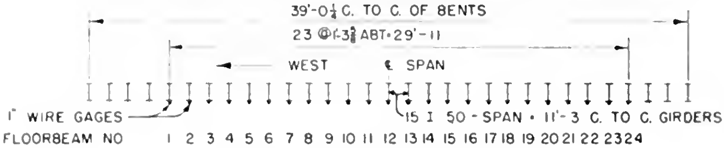
CROSS SECTION ON ℄ OF TEST TRACK

TEST TRAIN	EASTBOUND																	
	LOCOMOTIVE TYPE 2-8-4												LOCO. TYPE 4-6-4					
	PM 1217			PM 1223			TENDER			FRT. CAR			NYC 5408			NYC 5234		
RUN NO.	10			27									9			13		
SPEED IN MPH	6.4			55.7									6.3			35.7		
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST DRIVER AT																	
	8.8' EAST OF ℄ SPAN			12.0' EAST OF ℄ SPAN			78.9' EAST OF ℄ SPAN			744.8' EAST OF ℄ SPAN			5.0' EAST OF ℄ SPAN			1.7' EAST OF ℄ SPAN		
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO.	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
1	2.90	2.10	1.46	3.30	2.40	1.10	3.10	0.90	1.37	1.30	0.70	1.23	2.30	1.80	1.40	2.50	2.40	1.31
2	2.60	1.90	1.31	3.30	2.00	1.10	2.80	1.00	1.24	1.40	1.00	1.32	2.10	1.60	1.28	2.40	2.40	1.26
3	1.90	1.50	0.96	2.70	1.40	0.90	2.00	0.60	0.89	1.10	1.00	1.04	1.50	1.20	0.91	1.80	1.60	0.94
4	1.90	1.70	0.96	2.70	1.70	0.90	1.90	0.60	0.84	1.00	1.00	0.94	1.60	1.50	0.98	1.90	1.70	1.00
5	2.50	2.40	1.26	3.10	2.60	1.03	2.10	0.80	0.93	1.30	1.20	1.23	2.00	2.00	1.22	2.50	2.10	1.31
6	2.00	1.90	1.01	2.40	2.00	0.80	1.40	0.50	0.62	1.30	1.30	1.23	1.70	1.70	1.04	1.90	1.80	1.00
7	2.60	2.50	1.31	3.10	3.10	1.03	2.10	1.20	0.93	1.30	1.30	1.23	2.30	2.30	1.40	2.50	2.20	1.31
8	2.40	2.40	1.21	2.90	2.90	0.97	2.10	1.30	0.93	1.20	1.00	1.13	2.20	2.20	1.34	2.40	2.10	1.26
9	1.50	1.50	0.76	2.00	2.00	0.67	1.40	1.10	0.62	0.80	0.60	0.75	1.40	1.40	0.85	1.40	1.30	0.73
10	2.00	1.90	1.01	3.00	3.00	1.00	1.80	1.70	0.80	1.00	0.70	0.94	1.60	1.60	0.98	1.90	1.70	1.00
11	1.50	1.40	0.76	2.60	2.60	0.87	1.70	1.60	0.75	1.00	0.80	0.94	1.50	1.50	0.91	1.60	1.40	0.84
12	1.00	1.00	0.50	2.10	2.10	0.70	1.40	1.40	0.62	0.70	0.50	0.66	1.00	1.00	0.61	1.00	0.90	0.52
13	1.20	1.20	0.61	2.70	2.70	0.90	1.80	1.80	0.80	0.90	0.90	0.85	0.90	0.90	0.55	1.20	1.20	0.63
14	1.80	1.80	0.91	3.00	3.00	1.00	2.40	2.40	1.06	0.80	0.80	0.75	1.20	1.10	0.73	1.80	1.80	0.94
15	1.10	1.10	0.56	2.10	2.10	0.70	1.90	1.90	0.84	0.70	0.70	0.66	0.80	0.60	0.49	1.20	1.20	0.63
16	1.00	1.00	0.50	2.20	2.10	0.73	1.90	1.80	0.84	0.70	0.50	0.66	1.50	0.60	0.91	1.00	1.00	0.52
17	1.60	1.50	0.81	3.00	3.00	1.00	2.70	2.70	1.19	0.80	0.60	0.75	1.30	1.20	0.79	1.50	1.20	0.79
18	2.50	2.10	1.26	4.30	4.30	1.43	3.50	3.30	1.55	1.20	0.50	1.13	1.90	1.80	1.16	2.20	1.50	1.15
19	1.70	1.30	0.86	2.70	2.70	0.90	2.20	1.90	0.98	0.80	0.30	0.75	1.40	1.10	0.85	1.90	1.00	1.00
20	2.20	1.30	1.11	3.40	3.30	1.13	2.70	2.40	1.19	1.10	0.20	1.04	1.70	1.30	1.04	2.10	1.00	1.10
21	1.70	0.90	0.86	3.20	2.80	1.07	2.40	2.00	1.06	1.00	0.20	0.94	1.10	0.70	0.67	1.60	0.60	0.84
22	2.60	1.30	1.31	4.30	3.60	1.43	3.30	2.20	1.46	1.50	0.20	1.41	2.10	1.30	1.28	2.40	0.90	1.26
23	3.00	1.50	1.51	4.50	2.00	1.50	3.20	2.10	1.42	1.50	0	1.41	2.40	1.20	1.46	2.80	0.90	1.47
24	2.30	1.20	1.16	3.50	1.30	1.17	2.40	1.20	1.06	1.10	0	1.04	1.80	1.10	1.10	2.30	0.70	1.20
AVERAGE	1.98			3.00			2.26			1.06			1.64			1.91		
STATIC *														4.07			3.92	
DYNAMIC *														6.54			6.29	

FOR NOTES SEE FIG. 20.

FIG 24
NEW YORK CENTRAL RAILROAD BRIDGE TESTS
39'-0¼ THROUGH GIRDER SPAN – BALLASTED CONCRETE LINED STEEL PLATE FLOOR

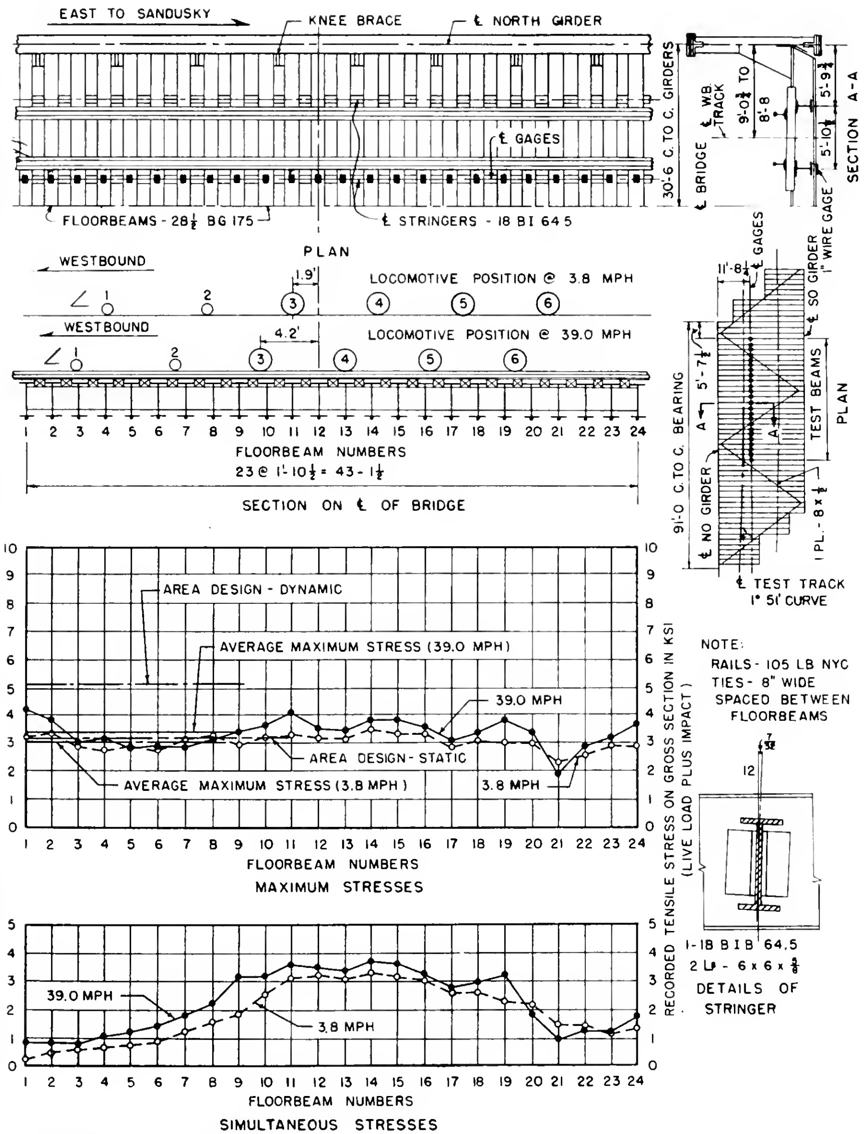
RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ OF TEST TRACK

TEST TRAIN	EASTBOUND																				
	LOCOMOTIVE TYPE 4 – 6 – 4																				
	NYC 5260			NYC 5302			TENDER			NYC 5414			NYC 5260			3 AXLE CAR			NYC 5318		
RUN NO.	1*			18						15			23						4		
SPEED IN MPH	42.5			64.0						72.4			75.0						84.0		
LOCOMOT POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT																				
	2.0' WEST OF ℄ SPAN			10.0' EAST OF ℄ SPAN			72.5' EAST OF ℄ SPAN			12.3' EAST OF ℄ SPAN			36' EAST OF ℄ SPAN			79.63' EAST OF ℄ SPAN			5.5' EAST OF ℄ SPAN		
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
FLOOR-BEAM NO	MAX.	SIMULT	RATIO	MAX.	SIMULT	RATIO	MAX.	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
1	2.80	2.20	1.34	3.40	2.50	1.43	3.50	1.20	1.48	3.20	1.80	1.27	3.30	2.80	1.19	1.80	0.60	1.40	3.60	2.60	1.21
2	2.80	2.00	1.34	3.10	2.30	1.30	3.20	0.90	1.35	2.90	1.60	1.15	3.00	2.60	1.08	1.40	0.50	1.09	3.40	2.40	1.14
3	2.00	1.50	0.96	2.10	1.60	0.88	2.30	0.70	0.97	2.30	0.90	0.91	2.40	1.70	0.87	1.10	0.60	0.85	2.80	1.70	0.94
4	2.00	1.50	0.96	2.20	1.60	0.92	2.40	0.50	1.01	2.30	1.00	0.91	2.70	2.00	0.98	1.10	0.60	0.85	2.90	1.90	0.98
5	2.30	2.30	1.10	2.80	1.90	1.18	2.50	0.60	1.05	3.00	1.20	1.19	3.10	3.00	1.12	1.50	0.70	1.16	3.60	2.50	1.21
6	2.00	1.80	0.96	2.40	1.50	1.01	1.70	0.40	0.72	2.30	1.20	0.91	2.50	1.90	0.90	1.40	0.90	1.09	2.90	2.10	0.98
7	2.30	2.20	1.10	2.80	2.30	1.18	2.10	0.80	0.89	2.50	1.70	0.99	2.90	2.70	1.05	1.40	0.90	1.09	3.10	2.50	1.04
8	2.30	2.00	1.10	2.80	2.40	1.18	1.60	0.60	0.68	2.50	1.20	0.99	2.70	2.70	0.98	1.70	1.00	1.32	3.20	2.50	1.08
9	1.50	1.50	0.72	1.60	1.60	0.67	1.00	0.70	0.42	1.90	1.10	0.75	1.60	1.60	0.58	1.00	0.70	0.78	2.20	1.60	0.74
10	2.20	2.10	1.05	2.30	2.30	0.97	2.00	1.20	0.84	2.50	1.80	0.99	2.90	2.80	1.05	1.40	1.10	1.09	2.90	2.30	0.98
11	1.80	1.80	0.86	1.80	1.70	0.76	1.40	1.10	0.59	2.00	1.90	0.79	2.50	2.50	0.90	1.10	0.90	0.85	2.10	2.10	0.71
12	1.10	1.10	0.53	1.20	1.20	0.50	1.00	1.00	0.42	1.20	1.20	0.47	1.70	1.70	0.61	0.80	0.80	0.62	1.50	1.50	0.51
13				1.70	1.70	0.71	1.50	1.50	0.63	2.10	2.10	0.83	2.00	2.00	0.72	0.90	0.90	0.70	2.10	2.10	0.71
14				2.00	2.00	0.84	2.10	2.10	0.89	2.60	2.60	1.03	2.30	1.00	0.83	1.30	1.30	1.01	2.70	2.50	0.91
15				1.40	1.40	0.59	1.70	1.70	0.72	2.10	1.90	0.83	1.70	0.80	0.61	1.00	0.90	0.78	2.00	1.80	0.67
16				1.50	1.10	0.63	1.80	1.60	0.76	1.80	1.80	0.71	1.50	0.70	0.54	0.90	0.70	0.70	1.80	1.80	0.61
17				1.90	1.40	0.80	2.40	1.90	1.01	2.20	1.90	0.87	2.30	0.80	0.83	1.10	0.70	0.85	2.30	1.90	0.77
18				2.90	2.30	1.22	3.70	2.60	1.56	3.30	2.70	1.30	3.70	1.20	1.34	1.70	1.10	1.32	4.00	3.00	1.35
19				2.70	2.30	1.13	3.40	1.80	1.44	2.40	1.60	0.95	3.50	0.90	1.26	1.40	0.40	1.09	2.90	1.60	0.98
20				2.60	2.20	1.09	3.10	1.20	1.31	3.10	2.00	1.23	3.60	0.70	1.30	1.40	0.30	1.09	3.90	1.70	1.31
21				2.30	1.90	0.97	2.70	0.80	1.14	2.40	1.40	0.95	3.20	0.50	1.16	1.00	0.20	0.78	3.30	1.10	1.11
22				3.30	2.30	1.39	3.50	1.00	1.48	3.50	2.20	1.38	4.10	0.70	1.48	1.70	0.10	1.32	4.00	1.40	1.35
23				3.50	2.30	1.47	3.50	0.80	1.48	3.70	2.20	1.46	4.10	0.70	1.48	1.60	0	1.24	4.50	1.50	1.51
24				2.90	1.80	1.22	2.70	0.40	1.14	2.80	1.80	1.11	3.20	0.50	1.16	1.30	0	1.01	3.40	1.20	1.14
AVERAGE	2.09			2.38			2.37			2.53			2.77			1.29			2.97		
STATIC *	3.92			3.92			3.92			4.07			3.92						3.92		
DYNAMIC *	6.29			6.29			5.52			6.54			6.29						6.29		

NOTE: * SIMULTANEOUS READINGS FOR RUN NO 1 TAKEN AT MAXIMUM FOR FLOORBEAM 12.
FOR NOTES SEE FIG. 20.



LOCOMOTIVES AND SYMBOLS:

○ RUN 1 - NYC 2872 (4-8-2) @ 3.8 MPH WB.
● RUN 12 - NYC 2841 (4-8-2) @ 39.0 MPH WB.
FOR TABULATION OF STRESSES SEE FIGS. 26 TO 28 INCL.

FIG. 25
NYC RR BRIDGE TESTS
93'-5 T.P.G. SPAN
OPEN TIMBER FLOOR
LOCATION OF GAGES AND TYPICAL RECORDED STRESSES IN TRANSVERSE FLOORBEAMS

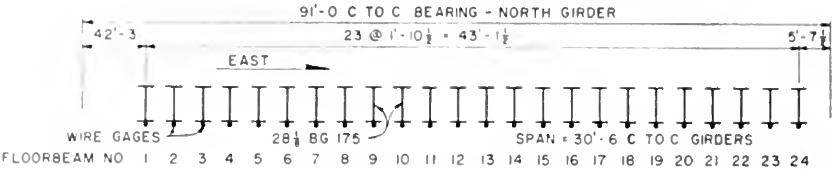
FIG 26

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

93'-5 THROUGH GIRDER SPAN - OPEN TIMBER FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS

91'-0 C TO C BEARING - NORTH GIRDER



SECTION ON ℄ BETWEEN GIRDERS

TEST TRAIN	WESTBOUND																	
	LOCOMOTIVE TYPE 4-8-2																	
	NYC 2872			NYC 2784			NYC 2877			NYC 2744			NYC 2841			TENDER		
RUN NO	1			7			2			10			12					
SPEED IN MPH	38			54			69			38 6			39 0					
LOCOMOT. POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT																	
	19' WEST OF ℄ FB 12			6 5' WEST OF ℄ FB 12			5 9' WEST OF ℄ FB 12			4 7' WEST OF ℄ FB 12			4 2' WEST OF ℄ FB 12			44 3' WEST OF ℄ FB 12		
COL NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO
1	3.20	0.25	1.06	3.70	0.50	1.15	3.05	0.70	1.06				4.25	0.85	1.27	3.60	2.20	1.18
2	3.35	0.55	1.11	3.55	0.70	1.10	3.20	1.10	1.11	4.60	1.30	1.21	3.85	0.85	1.15	3.20	1.70	1.05
3	2.85	0.60	0.95	3.00	0.70	0.92	2.75	1.10	0.95	3.50	1.00	0.92	3.00	0.80	0.90	2.80	1.60	0.92
4	2.75	0.65	0.92	3.00	0.85	0.92	2.75	1.25	0.95	3.50	1.10	0.92	3.20	1.05	0.96	3.15	1.55	1.04
5	2.85	0.80	0.95	2.75	1.15	0.85	2.80	1.60	0.97	3.10	1.30	0.82	2.85	1.20	0.85	2.90	1.20	0.95
6	2.75	0.95	0.92	2.70	1.35	0.84	2.45	1.60	0.85	3.05	1.60	0.80	2.80	1.45	0.84	2.70	1.05	0.89
7	3.05	1.25	1.01	3.05	1.80	0.95	2.60	2.00	0.90	3.35	2.10	0.88	2.85	1.85	0.85	2.65	1.20	0.87
8	3.20	1.65	1.06	3.40	2.40	1.05	2.85	2.45	0.99	3.90	2.70	1.03	3.15	2.30	0.94	3.00	1.30	0.99
9	2.95	1.90	0.98	3.40	2.80	1.05	3.00	2.65	1.04	4.15	3.45	1.10	3.40	3.10	1.02	2.80	1.90	0.92
10	3.20	2.55	1.06	3.30	2.85	1.02	2.95	2.65	1.02	3.75	3.30	0.99	3.60	3.25	1.08	2.75	2.45	0.90
11	3.30	3.10	1.10	3.60	3.45	1.11	3.10	2.95	1.08	4.15	3.90	1.10	4.05	3.65	1.21	3.30	3.15	1.08
12	3.20	3.20	1.06	3.55	3.55	1.10	3.05	3.05	1.06	4.00	4.00	1.06	3.55	3.55	1.06	3.00	3.00	0.99
13	3.15	3.15	1.05	3.20	3.20	0.99				3.80	3.80	1.00	3.40	3.40	1.02	2.70	2.70	0.89
14	3.45	3.30	1.15	3.50	3.40	1.08				4.00	3.60	1.06	3.80	3.75	1.14	2.90	2.90	0.95
15	3.35	3.20	1.11	3.60	3.40	1.11				4.10	3.35	1.08	3.85	3.65	1.15	3.00	2.35	0.99
16	3.30	3.05	1.10	3.55	3.00	1.10				3.80	2.90	1.00	3.55	3.30	1.06	3.25	1.80	1.07
17	2.85	2.55	0.95	3.35	2.50	1.03				3.60	2.35	0.95	3.05	2.80	0.91	3.10	1.20	1.02
18	3.05	2.65	1.01	3.40	2.30	1.05				5.15	2.80	1.36	3.35	2.85	1.00	3.30	1.35	1.08
19	3.00	2.35	1.00	3.35	1.85	1.03				4.15	1.90	1.10	3.75	3.20	1.12	4.50	2.45	1.48
20	3.00	2.20	1.00	3.40	1.55	1.05				3.70	1.40	0.98	3.35	1.90	1.00	3.10	1.00	1.02
21	2.25	1.50	0.75	2.60	1.05	0.81				3.00	1.00	0.79	1.95	1.00	0.58	1.85	0.95	0.61
22	2.55	1.45	0.85	2.60	1.00	0.81				3.25	1.05	0.86	2.85	1.25	0.85	2.85	1.70	0.94
23	2.90	1.25	0.96	2.80	1.00	0.87				3.55	1.30	0.94	3.15	1.30	0.94	3.10	2.30	1.02
24	2.85	1.35	0.95	3.15	1.40	0.98				3.95	1.85	1.04	3.55	1.75	1.06	3.40	3.40	1.12
AVERAGE	3.01			3.23			2.88			3.79			3.34			3.04		
STATIC*	3.17			3.17			3.17			3.17			3.17			2.94		
DYNAMIC*	5.19			5.19			5.19			5.19			5.19			4.23		

NOTE STRESSES SHOWN ARE TENSION VALUES IN KSI

"MAX" ARE MAXIMUM RECORDED STRESSES AT EACH FLOORBEAM.

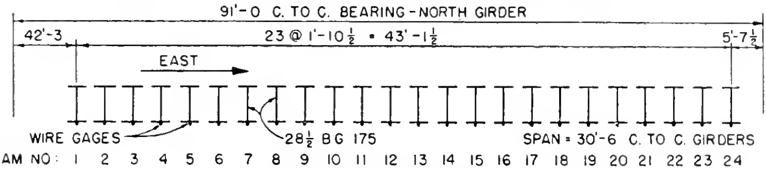
"SIMULT" - SIMULTANEOUS STRESS WITH MAXIMUM STRESS AT FLOORBEAM 12

"RATIO" OF RECORDED MAXIMUM STRESS TO AVERAGE RECORDED MAXIMUM STRESS

* AREA DESIGN

FIG. 27
NEW YORK CENTRAL RAILROAD BRIDGE TESTS
93'-5 THROUGH GIRDER SPAN — OPEN TIMBER FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



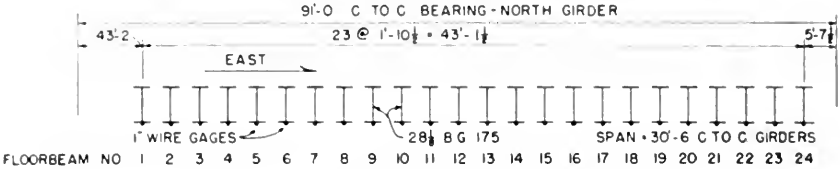
SECTION ON ℄ BETWEEN GIRDERS

TEST TRAIN	WESTBOUND																	
	LOCOMOTIVE TYPE: 4-8-2									LOCOMOTIVE TYPE: 2-8-2								
	NYC 2884			TENDER			FRT. CARS			NYC 2277			NYC 2282			NYC 2282		
RUN NO.	4									5			3*			9		
SPEED IN MPH	38.8									1.9			9.4			22.4		
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST DRIVER AT 1.9' WEST OF ℄ FB. 12			38.9' WEST OF ℄ FB. 12						5.5' WEST OF ℄ FB. 12			5.3' WEST OF ℄ FB. 12			10.1' WEST OF ℄ FB. 12		
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO.	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX	SIMULT.	RATIO
1	4.00	0	1.22	2.75	1.10	0.89	1.40		1.65	3.30	0.45	1.10	3.35		1.12	3.90	1.00	1.18
2	4.10	0.65	1.25	4.15	1.25	1.34	1.05		1.23	3.30	0.70	1.10	3.30		1.11	3.90	1.40	1.18
3	3.25	1.05	0.99	1.90	1.60	0.61	0.85		1.00	2.95	0.85	0.98	2.85		0.96	3.45	1.20	1.05
4	3.00	1.10	0.92	3.05	1.50	0.99	0.60		0.71	2.90	0.95	0.97	2.80		0.94	3.35	1.35	1.02
5	2.75	1.10	0.84	2.70	1.35	0.87	0.80		0.94	2.75	1.10	0.92	2.80		0.94	2.55	1.30	0.77
6	2.75	1.20	0.84	2.80	0.85	0.91	0.65		0.77	2.60	1.20	0.87	2.80		0.94	3.00	1.90	0.91
7	3.10	1.70	0.95	3.20	1.10	1.04	0.70		0.82	2.80	1.70	0.93	2.80		0.94	3.20	2.20	0.97
8	3.60	2.30	1.10	3.50	1.65	1.13	0.85		1.00	3.15	2.40	1.05	2.95		0.99	3.50	2.50	1.06
9	4.05	3.15	1.24	3.40	2.35	1.10	0.95		1.12	3.15	2.65	1.05	3.05		1.02	3.25	2.80	0.99
10	3.50	3.00	1.07	3.05	2.70	0.99	0.85		1.00	3.30	2.95	1.10	3.10		1.04	3.15	3.05	0.96
11	3.50	3.50	1.07	3.45	3.45	1.12	0.95		1.12	3.30	3.20	1.10	3.30		1.11	3.50	3.50	1.06
12	3.35	3.35	1.02	3.35	3.35	1.08	0.75		0.88	3.15	3.15	1.05	3.15		1.06	3.40	3.40	1.03
13	2.60	1.85	0.80	2.60	2.15	0.84	0.75		0.88	3.00	2.90	1.00	2.90	2.90	0.97	3.25	3.25	0.99
14	3.15	2.25	0.96	2.85	2.00	0.92	0.75		0.88	3.35	3.10	1.12	3.30	3.30	1.11	3.60	3.20	1.09
15	3.40	2.30	1.04	3.10	1.45	1.00	0.70		0.82	3.45	3.10	1.15	3.35	3.25	1.12	3.60	2.95	1.09
16	3.35	2.20	1.02	3.05	1.10	0.99	0.90		1.06	3.20	2.75	1.07	3.20	3.00	1.07	3.55	2.40	1.08
17	3.05	2.10	0.93	2.85	0.80	0.92	0.80		0.94	3.00	2.25	1.00	2.95	2.50	0.99	3.30	1.85	1.00
18	3.95	2.70	1.21	3.85	2.25	1.25	0.80		0.94	2.95	1.80	0.98	2.85	2.15	0.96	3.50	2.00	1.06
19	3.10	2.35	0.95	3.35	1.30	1.08				3.05	1.50	1.02	3.00	1.75	1.01	3.25	1.95	0.99
20	3.05	2.30	0.93	3.20	1.65	1.04	0.80		0.94	2.85	1.15	0.95	2.85	1.30	0.96	3.20	1.35	0.97
21	2.65	1.90	0.81	2.65	1.90	0.86	0.80		0.94	2.30	0.90	0.77	2.40	0.95	0.81	2.70	1.20	0.82
22	2.70	1.60	0.83	2.70	2.55	0.87	1.00		1.18	2.50	0.90	0.83	2.60	0.95	0.87	2.70	1.10	0.82
23	2.70	1.40	0.83	3.00	2.90	0.97	0.90		1.06	2.80	1.00	0.93	2.90	0.90	0.97	3.05	1.00	0.93
24	3.90	2.20	1.19	3.55	3.05	1.15	0.90		1.06	2.90	0.95	0.97	3.05	1.00	1.02	3.40	1.20	1.03
AVERAGE	3.27			3.09			0.85			3.00			2.98			3.30		
STATIC	3.17			2.94						3.56			3.56			3.56		
DYNAMIC	5.19			4.23						5.82			5.82			5.82		

NOTE: * SIMULTANEOUS FOR RUN NO. 3 AT FLOORBEAM 13.
FOR OTHER NOTES SEE FIG. 26.

FIG 28
NEW YORK CENTRAL RAILROAD BRIDGE TESTS
93'-5 THROUGH GIRDER SPAN - OPEN TIMBER FLOOR

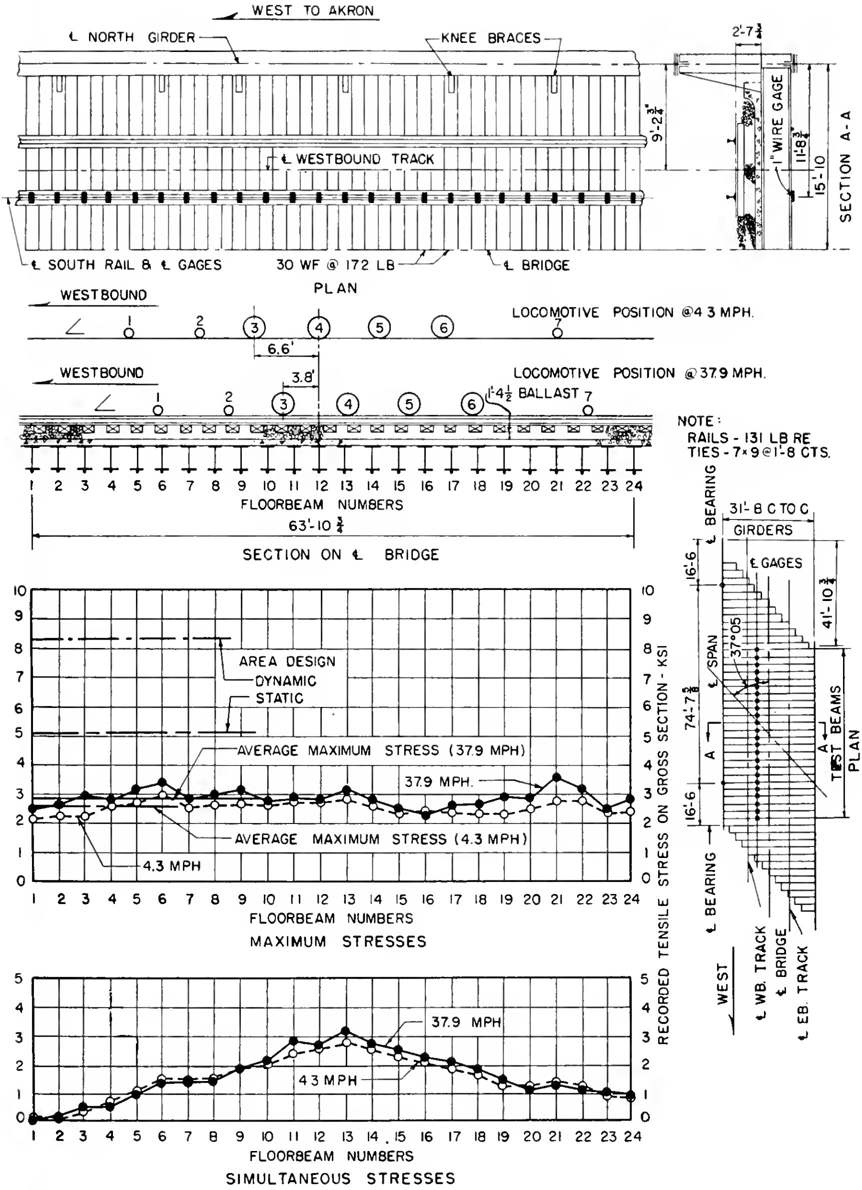
RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



SECTION ON ℄ BETWEEN GIRDERS

TEST TRAIN	WESTBOUND																	
	2-8-2			LOCOMOTIVE TYPE 4-6-4														
	NYC 1713			NYC 5393			TENDER			FRT CARS			NYC 5394			TENDER		
RUN NO.	8			6									11					
SPEED IN MPH	33.9			27.8									28.6					
LOCOMOT. POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT																	
	7.9' WEST OF ℄ FB. 12			8.4' WEST OF ℄ FB. 12			44.8' WEST OF ℄ FB. 12						8.4' WEST OF ℄ FB. 12			45.2' WEST OF ℄ FB. 12		
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO.	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO
1				3.30	0.60	1.07	2.20	2.00	0.86	1.55		1.18	2.80	1.80	1.03	2.90	2.45	1.14
2	3.95	0.80	1.22	3.15	1.25	1.02	3.00	1.95	1.18	1.65		1.26	2.90	2.10	1.06	2.75	2.20	1.08
3	3.20	0.70	0.99	2.80	1.25	0.91	2.55	1.55	1.00	1.45		1.11	2.60	2.20	0.95	2.50	1.85	0.98
4	3.25	0.80	1.01	2.75	1.40	0.89	2.10	1.30	0.82	1.50		1.14	2.45	2.25	0.90	2.55	1.45	1.00
5	2.90	0.95	0.90	2.65	1.75	0.86	2.30	1.20	0.90	1.40		1.07	2.30	2.30	0.84	2.20	1.10	0.86
6	3.00	1.20	0.93	2.65	2.20	0.86	2.25	1.10	0.88	1.25		0.95	2.60	2.60	0.95	2.25	1.10	0.88
7	3.15	1.60	0.97	2.80	2.70	0.91	2.50	1.20	0.98	1.30		0.99	2.70	2.70	0.99	2.10	1.10	0.82
8	3.35	1.95	1.04	3.25	3.25	1.06	2.85	1.55	1.12	1.40		1.07	3.00	3.00	1.10	2.30	1.45	0.90
9	3.35	2.50	1.04	3.30	3.30	1.07	2.75	2.00	1.08	1.45		1.11	3.10	3.10	1.14	2.65	2.00	1.04
10	3.15	2.80	0.97	3.40	3.40	1.10	2.50	2.30	0.98	1.50		1.14	3.20	3.20	1.17	2.55	2.20	1.00
11	3.10	2.95	0.96	3.55	3.55	1.15	2.60	2.60	1.02	1.40		1.07	3.30	3.30	1.21	2.55	2.55	1.00
12	3.00	3.00	0.93	3.35	3.35	1.09	2.45	2.45	0.96	1.35		1.03	3.05	3.05	1.12	2.30	2.30	0.90
13	2.90	2.90	0.90	3.10	3.10	1.01	2.35	1.80	0.92	1.15		0.88	3.00	3.00	1.10	2.60	2.10	1.02
14	3.30	3.30	1.02	3.35	3.35	1.09	2.70	1.60	1.06	1.15		0.88	3.10	3.10	1.14	2.90	1.65	1.14
15	3.60	3.35	1.12	3.50	3.10	1.14	2.70	1.30	1.06	1.30		0.99	3.15	3.05	1.15	2.85	1.40	1.12
16	3.60	3.00	1.12	3.25	2.65	1.06	2.50	1.05	0.98	1.20		0.92	2.90	2.60	1.06	2.60	1.00	1.02
17	3.05	2.40	0.94	2.90	2.60	0.94	2.40	0.70	0.94	1.05		0.80	2.60	2.15	0.95	2.25	0.80	0.88
18	3.65	2.40	1.13	3.10	2.10	1.01	2.65	1.90	1.04	1.25		0.95	2.85	2.40	1.04	2.75	1.20	1.08
19	3.25	2.00	1.01	3.20	2.10	1.04	2.70	0.80	1.06	1.25		0.95	2.55	2.10	0.93	3.05	1.30	1.20
20	2.95	1.50	0.91	3.00	1.80	0.97	2.40	0.90	0.94	1.20		0.92	2.45	1.95	0.90	2.75	1.15	1.08
21	2.45	1.25	0.76	2.35	1.50	0.76	2.25	1.10	0.88	1.00		0.76	1.95	1.50	0.71	2.10	1.10	0.82
22	2.70	1.30	0.84	2.65	1.45	0.86	2.55	1.30	1.00	1.20		0.92	2.00	1.30	0.73	2.15	1.35	0.84
23	3.10	1.30	0.96	3.05	1.35	0.99	3.00	1.65	1.18	1.30		0.99	2.35	1.40	0.86	2.80	1.85	1.10
24	4.30	2.00	1.33	3.40	1.40	1.10	3.10	2.10	1.22	1.30		0.99	2.60	1.25	0.95	2.65	1.90	1.04
AVERAGE	3.23			3.08			2.55			1.31			2.73			2.55		
STATIC	3.13			2.83			2.44						2.83			2.44		
DYNAMIC	5.12			4.63			3.50						4.63			3.50		

FOR NOTES SEE FIG 26



LOCOMOTIVES & SYMBOLS
○ RUN 3 B&O 5654 (4-8-2) @ 4.3 MPH. WB.
● RUN 16 B&O 5661 (4-8-2) @37.9 MPH WB.
FOR TABULATION OF STRESSES SEE FIGS 30-32

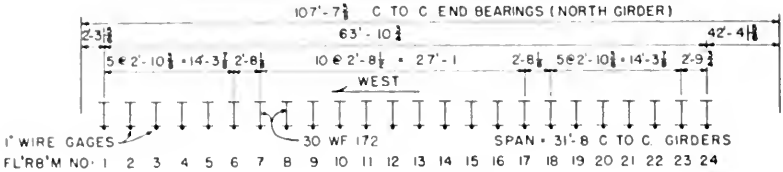
FIG. 29
B&O. RR BRIDGE TESTS
17'-6 & 74'-7⅝ T.P.G. SPANS
BALLASTED CONCRETE SLAB FLOOR
LOCATION OF GAGES AND TYPICAL RECORDED STRESSES IN TRANSVERSE FLOORBEAMS

FIG 30

BALTIMORE AND OHIO RAILROAD BRIDGE TESTS

17'-6 & 74'-7⅝ THROUGH GIRDER SPANS – BALLASTED CONCRETE SLAB FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



SECTION ON ℄ OF BRIDGE

TEST TRAIN	WESTBOUND																	
	LOCOMOTIVE TYPE: 2 AXLE DIESEL									3 AXLE DIESEL						2-8-0		
	B&O 85			B&O 103			B&O 82			B&O 62			B&O 65			B&O 2766		
RUN NO	14			15			12			7			13			5		
SPEED IN MPH	42			44.1			71.1			46			54			27.4		
LOCOMOT POSITION FOR SIMULTAN. STRESS	FIRST DRIVER AT 49.8' WEST OF ℄ FB 12			137.8' WEST OF ℄ FB 12			33.9' WEST OF ℄ FB. 12			49.1' WEST OF ℄ FB. 12			49.4' WEST OF ℄ FB. 12			6.8' WEST OF ℄ FB. 12		
COL NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO.	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO
1	1.35	0.20	0.81	1.45	0.70	0.82	1.50	1.25	0.85	1.35	0.60	0.78	1.60	0.70	0.91	1.80	0	0.85
2	1.50	0.40	0.90	1.60	0.80	0.91	1.65	1.35	0.94	1.75	0.50	1.01	1.60	0.40	0.91	2.10	0.05	0.99
3	1.60	0.75	0.96	1.80	0.75	1.02	2.00	1.55	1.14	1.70	0.30	0.98	1.70	0.25	0.97	2.05	0.05	0.96
4	1.70	1.15	1.02	1.70	0.60	0.97	1.90	1.00	1.08	1.85	0.20	1.07	1.85	0.20	1.06	2.30	0.25	1.08
5	1.85	1.55	1.11	1.85	0.75	1.04	1.90	0.65	1.08	1.85	0.25	1.07	1.95	0.20	1.11	2.30	0.40	1.08
6	1.85	1.70	1.11	1.95	1.20	1.11	2.05	0.70	1.16	1.90	0.45	1.10	1.95	0.35	1.11	2.50	0.75	1.17
7	1.70	1.60	1.02	1.70	1.20	0.97	1.70	0.55	0.97	1.70	0.45	0.98	1.70	0.35	0.97	2.10	0.70	0.99
8	1.70	1.65	1.02	1.75	1.20	1.00	1.90	0.65	1.08	1.80	0.55	1.04	1.80	0.60	1.03	2.20	0.90	1.03
9	1.60	1.55	0.95	1.75	1.55	1.00	1.95	0.95	1.11	1.90	0.95	1.10	1.85	0.95	1.06	2.05	1.25	0.96
10	1.70	1.50	1.02	1.70	1.30	0.97	1.85	1.25	1.05	1.80	1.30	1.04	1.80	1.30	1.03	1.90	1.60	0.89
11	1.65	1.50	1.00	1.75	1.75	1.00	1.85	1.60	1.05	1.80	1.55	1.04	1.80	1.60	1.03	2.10	2.10	0.99
12	1.55	1.55	0.93	1.70	1.70	0.97	1.65	1.65	0.94	1.65	1.65	0.95	1.70	1.60	0.97	2.05	2.05	0.96
13	1.90	1.90	1.14	2.00	2.00	1.14	1.90	1.90	1.08	1.80	1.80	1.04	2.00	2.00	1.14	2.20	2.20	1.03
14	1.70	1.60	1.02	1.85	1.75	1.04	1.75	1.60	1.00	1.70	1.65	0.98	1.75	1.70	1.00	2.10	1.90	0.99
15	1.60	1.45	0.96	1.70	1.45	0.97	1.70	1.40	0.97	1.55	1.40	0.90	1.60	1.35	0.91	1.90	1.55	0.89
16	1.50	1.20	0.90	1.65	1.40	0.94	1.60	1.30	0.91	1.60	1.25	0.92	1.60	1.25	0.91	2.05	1.35	0.96
17	2.10	1.60	1.26	1.90	1.40	1.08	1.70	1.45	0.97	1.70	1.15	0.98	1.80	1.20	1.03	2.20	0.90	1.03
18	1.60	0.80	0.96	1.80	1.05	1.02	1.60	1.60	0.91	1.80	1.15	1.04	1.75	1.10	1.00	2.10	0.80	0.99
19	1.75	0.65	1.05	1.75	0.80	1.00	1.65	1.50	0.94	1.70	1.20	0.98	1.80	1.20	1.03	2.05	0.50	0.96
20	1.55	0.60	0.93	1.70	0.70	0.97	1.60	1.30	0.91	1.85	1.45	1.07	1.65	1.30	0.94	2.35	0.50	1.10
21	1.80	0.70	1.08	2.35	1.35	1.34	2.20	1.90	1.25	1.85	1.65	1.07	1.85	1.45	1.06	2.70	0.95	1.27
22	1.75	1.05	1.05	1.90	1.10	1.08	1.65	0.85	0.94	1.90	1.85	1.10	1.80	1.75	1.03	2.30	0.75	1.08
23	1.40	1.15	0.84	1.45	1.20	0.82	1.55	0.55	0.88	1.45	1.40	0.84	1.55	1.50	0.89	1.90	0.75	0.89
24	1.50	1.35	0.90	1.60	1.35	0.91	1.55	0.25	0.88	1.50	1.50	0.87	1.60	1.55	0.91	1.85	0.70	0.87
AVERAGE	1.66			1.76			1.76			1.73			1.75			2.13		
STATIC *	3.23			3.04			3.23			3.66			3.66			4.86		
DYNAMIC *	4.64			4.36			4.64			5.26			5.26			7.95		

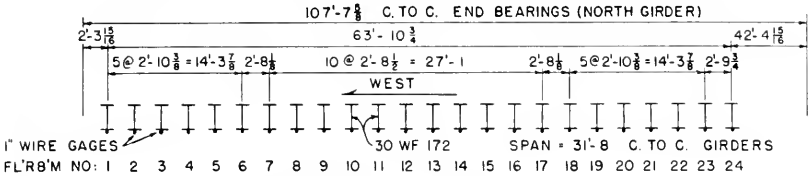
NOTES: STRESSES SHOWN ARE TENSION VALUES IN KSI.
"MAX." ARE MAXIMUM RECORDED STRESSES AT EACH FLOORBEAM
"SIMULT." SIMULTANEOUS STRESS WITH MAXIMUM STRESS AT FLOORBEAM 13.
"RATIO" OF RECORDED MAXIMUM STRESS TO AVERAGE RECORDED MAXIMUM STRESS.
* AREA DESIGN

FIG 31

BALTIMORE AND OHIO RAILROAD BRIDGE TESTS

17'-6 & 74'-7⅝ THROUGH GIRDER SPANS-BALLASTED - CONCRETE - SLAB - FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



SECTION ON ℄ OF BRIDGE

TEST TRAIN	WESTBOUND																	
	LOCO. TYPE: 2-8-2						LOCOMOTIVE: TYPE 4-8-2											
	B.&O. 4486			B.&O. 4447			B.&O. 5654									B.&O. 5589		
RUN NO.	1			10			3			2			4			8		
SPEED IN MPH.	39.4			44.0			4.3			4.6			4.8			18.8		
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST DRIVER AT																	
	9.6' WEST OF ℄ FB 12			3.5' WEST OF ℄ FB. 12			6.6' WEST OF ℄ FB. 12			6.4' WEST OF ℄ FB. 12			6.8' WEST OF ℄ FB. 12			9.9' WEST OF ℄ FB. 12		
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO.	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
1	2.20	0	0.71	2.35	0	0.73	2.10	0.10	0.83	2.05	0	0.81	2.05	0	0.82	2.05	0.25	0.84
2	3.05	0.20	0.98	2.95	0.05	0.92	2.20	0.15	0.87	2.30	0.15	0.91	2.30	0.10	0.92	2.35	0.55	0.95
3	3.70	0.75	1.19	4.00	0.40	1.25	2.20	0.35	0.87	2.40	0.35	0.95	2.35	0.30	0.94	2.55	1.00	1.03
4	3.10	0.50	1.00	3.45	0.30	1.08	2.60	0.70	1.02	2.55	0.70	1.01	2.60	0.65	1.04	2.70	1.25	1.09
5	3.05	0.70	0.98	3.65	0.50	1.14	2.70	1.15	1.06	2.60	1.05	1.03	2.55	1.00	1.02	2.70	1.50	1.09
6	3.40	1.20	1.10	3.75	0.95	1.17	2.95	1.60	1.16	2.85	1.45	1.13	2.80	1.40	1.12	2.75	1.95	1.11
7	2.85	1.30	0.92	2.85	0.95	0.89	2.55	1.45	1.00	2.60	1.40	1.03	2.60	1.45	1.04	2.50	1.80	1.01
8	3.00	1.70	0.97	3.10	1.10	0.97	2.60	1.60	1.02	2.70	1.60	1.07	2.50	1.50	1.00	2.65	1.90	1.07
9	3.15	2.00	1.02	3.35	1.50	1.04	2.65	1.90	1.04	2.70	1.90	1.07	2.60	1.80	1.04	2.75	2.25	1.11
10	2.70	2.10	0.87	3.00	2.00	0.94	2.65	2.05	1.04	2.60	2.00	1.03	2.50	1.95	1.00	2.50	2.15	1.01
11	3.05	2.50	0.98	3.25	2.60	1.01	2.75	2.45	1.08	2.70	2.40	1.07	2.60	2.25	1.04	2.55	2.40	1.03
12	2.80	2.15	0.90	2.85	2.70	0.89	2.75	2.60	1.08	2.70	2.50	1.07	2.60	2.45	1.04	2.40	2.25	0.97
13	3.00	3.00	0.97	3.55	3.55	1.11	2.85	2.85	1.12	2.80	2.80	1.09	2.75	2.75	1.10	2.50	2.50	1.01
14	3.05	3.00	0.98	3.50	3.50	1.09	2.60	2.60	1.02	2.55	2.55	1.01	2.60	2.60	1.04	2.50	2.35	1.01
15	3.10	2.15	1.00	3.20	3.10	1.00	2.40	2.35	0.95	2.35	2.30	0.93	2.40	2.35	0.96	2.25	2.10	0.91
16	3.15	2.65	1.02	3.20	2.60	1.00	2.45	2.15	0.96	2.30	2.15	0.91	2.40	2.20	0.96	2.20	1.90	0.89
17	3.10	2.20	1.00	3.15	2.25	0.98	2.40	1.95	0.95	2.35	2.00	0.93	2.30	2.00	0.92	2.35	1.85	0.95
18	3.00	1.75	0.97	3.05	1.90	0.95	2.40	1.70	0.95	2.35	1.65	0.93	2.35	1.70	0.94	2.45	1.90	0.99
19	2.85	1.40	0.92	3.20	1.70	1.00	2.35	1.35	0.93	2.35	1.30	0.93	2.40	1.40	0.96	2.50	1.75	1.01
20	4.20	1.80	1.35	3.10	1.50	0.97	2.50	1.35	0.98	2.40	1.30	0.95	2.50	1.40	1.00	2.40	1.35	0.97
21	4.05	1.80	1.31	3.95	2.15	1.23	2.75	1.50	1.08	2.85	1.45	1.13	2.80	1.70	1.12	2.80	1.65	1.13
22	3.05	0.85	0.98	3.10	1.15	0.97	2.80	1.25	1.10	2.90	1.30	1.15	2.85	1.25	1.14	2.60	1.25	1.05
23	2.80	0.90	0.90	2.60	1.00	0.81	2.35	0.90	0.93	2.35	0.90	0.93	2.35	0.90	0.94	2.10	1.15	0.85
24	3.00	0.95	0.97	2.90	1.00	0.90	2.40	0.90	0.95	2.40	0.90	0.95	2.50	0.90	1.00	2.40	1.45	0.97
AVERAGE	3.10			3.21			2.54			2.53			2.51			2.48		
STATIC	5.35			5.35			5.06			5.06			5.06			5.08		
DYNAMIC	8.74			8.74			8.28			8.28			8.28			8.30		

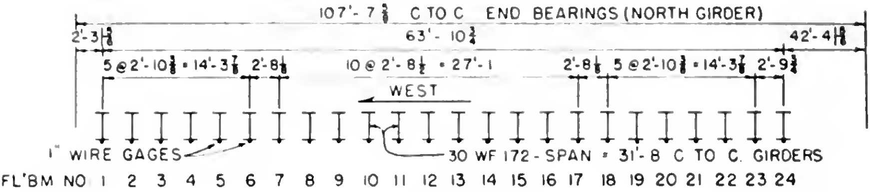
FOR NOTES SEE FIG 30.

FIG 32

BALTIMORE AND OHIO RAILROAD BRIDGE TESTS

17'-6 & 74'-7⅜ THROUGH GIRDER SPANS – BALLASTED CONCRETE SLAB FLOOR

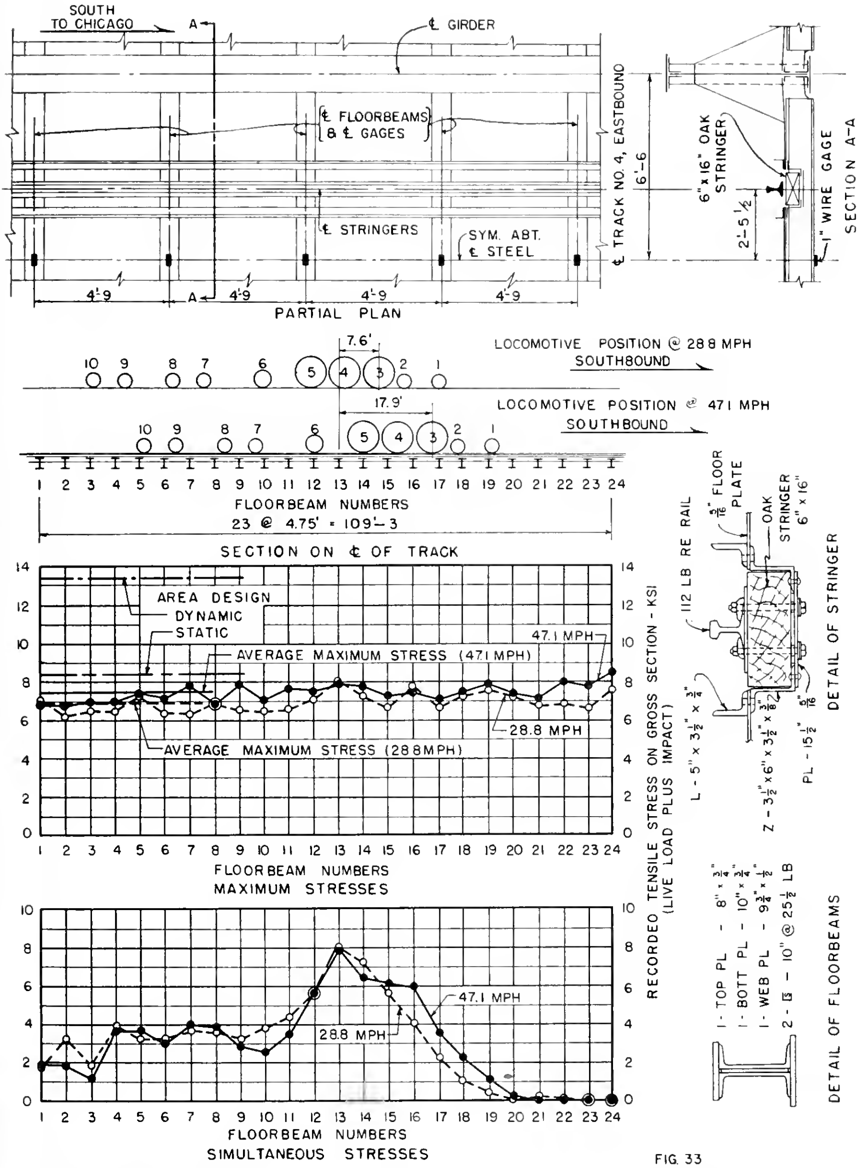
RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



SECTION ON ℄ OF BRIDGE

TEST TRAIN	WESTBOUND												EASTBOUND		
	LOCOMOTIVE TYPE: 4-8-2									LOCO. TYPE: 2-10-2					
	B.&O. 5653			B.&O. 5661			B.&O. 5660			B.&O. 6203			B.&O. 6181		
RUN NO.	9			16			11			10A			6 *		
SPEED IN MPH.	30.2			37.9			39.6			44.0			30 EST.		
LOCOMOT POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT														
	10.5' WEST OF ℄ FB 12			3.8' WEST OF ℄ FB. 12			6.5' WEST OF ℄ FB. 12			2.2' WEST OF ℄ FB 12					
COL. NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
FLOOR-BEAM NO.	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX	SIMULT.	RATIO
1	2.15	0.10	0.80	2.45	0	0.86	1.65	0	0.63	2.90	1.00	0.76	1.25		0.65
2	2.50	0.45	0.93	2.60	0.20	0.91	2.30	0.15	0.87	3.45	1.00	0.91	2.20		1.14
3	2.60	0.85	0.97	2.95	0.50	1.03	2.65	0.50	1.01	3.90	1.15	1.03	2.15		1.11
4	2.55	1.05	0.95	2.80	0.55	0.98	2.75	0.80	1.05	3.85	0.95	1.01	2.05		1.06
5	2.75	1.40	1.03	3.15	1.00	1.11	3.30	1.35	1.26	4.15	1.20	1.09	1.80		0.93
6	3.05	1.90	1.14	3.35	1.40	1.18	3.45	1.85	1.31	4.45	1.55	1.17	1.95		1.01
7	2.70	1.90	1.01	2.85	1.40	1.00	2.95	1.75	1.12	3.50	1.45	0.92	1.95		1.01
8	2.90	2.15	1.08	3.00	1.50	1.05	3.00	1.95	1.14	3.65	1.75	0.96	2.10		1.09
9	2.80	2.50	1.05	3.15	1.90	1.11	2.55	2.00	0.97	4.00	2.45	1.05	2.05		1.06
10	2.85	2.60	1.07	2.70	2.10	0.95	2.40	2.30	0.91	3.80	2.90	1.00	2.15		1.11
11	2.80	2.65	1.05	2.85	2.80	1.00	2.75	2.75	1.05	4.05	3.50	1.07	2.10		1.09
12	2.60	2.55	0.97	2.75	2.70	0.96	2.65	2.65	1.01	3.50	3.50	0.92	1.90		0.99
13	2.65	2.65	0.99	3.10	3.10	1.09	3.10	3.10	1.18	4.45	4.45	1.17	2.00		1.04
14	2.55	2.55	0.95	2.80	2.75	0.98	2.55	2.55	0.97	4.10	4.10	1.08	2.05		1.06
15	2.45	2.30	0.91	2.50	2.50	0.88	2.30	2.10	0.87	3.60	3.60	0.95	2.00		1.04
16	2.45	2.00	0.91	2.30	2.20	0.81	2.20	1.90	0.84	3.60	3.20	0.95	2.10		1.09
17	2.70	1.80	1.01	2.60	2.10	0.91	2.45	1.75	0.93	4.05	2.80	1.07	2.15		1.11
18	2.65	1.65	0.99	2.65	1.85	0.93	2.30	1.30	0.87	4.10	2.30	1.08	2.15		1.11
19	2.60	1.60	0.97	2.95	1.50	1.03	2.45	1.20	0.93	3.90	1.85	1.03	1.90		0.99
20	2.70	1.40	1.01	2.85	1.15	1.00	2.25	0.95	0.86	3.60	1.85	0.95	2.05		1.06
21	3.40	1.70	1.27	3.55	1.40	1.25	3.50	1.85	1.33	5.00	2.60	1.32	2.00		1.04
22	2.85	1.00	1.07	3.20	1.20	1.12	2.80	1.10	1.07	3.80	1.60	1.00	1.70		0.88
23	2.35	1.00	0.88	2.50	1.05	0.88	2.35	1.05	0.89	3.40	1.30	0.89	1.30		0.67
24	2.60	1.20	0.97	2.70	0.90	0.95	2.45	0.90	0.93	3.50	0.90	0.92	1.30		0.67
AVERAGE	2.68			2.85			2.63			3.80			1.93		
STATIC	5.06			5.06			5.06			5.94			3.48		
DYNAMIC	8.28			8.28			8.28			9.71			5.50		

NOTE: * RUN NO. 6 IS ON EASTBOUND TRACK.
FOR OTHER NOTES SEE FIG 30.



LOCOMOTIVES & SYMBOLS.

● RUN 111 – C&NW. 538 (4-6-2) @ 47.1 MPH SB
○ RUN 107 – C&NW. 505 (4-6-2) @ 28.8 MPH SB

FOR TABULATION OF STRESSES SEE FIG. 34.

FIG. 33

C & NW. RY BRIDGE TESTS
THROUGH GIRDER SPANS
OPEN DECK

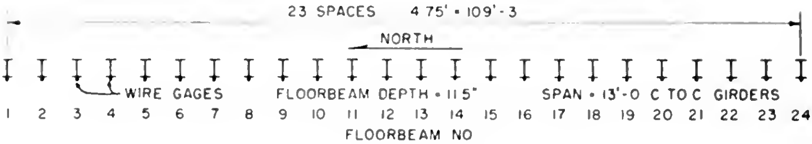
LOCATION OF GAGES AND TYPICAL RECORDED STRESSES IN TRANSVERSE FLOORBEAMS

FIG 34

CHICAGO AND NORTH WESTERN RAILWAY BRIDGE TESTS

THROUGH GIRDER SPANS – OPEN DECK

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



CROSS SECTION ON ℄ OF TEST TRACK

TEST TRAIN	SOUTHBOUND																	
	LOCOMOTIVE TYPE 4-6-2																	
	C&NW 505			C&NW 574			C&NW 531			C&NW 555			C&NW 579			C&NW 538		
RUN NO	107			108			129			115			125			111		
SPEED IN MPH	28.8			29.5			33.4			34.2			41.6			47.1		
LOCOMOT POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT																	
	7.6' SOUTH OF FB 13			7.3' SOUTH OF FB 13			6.8' SOUTH OF FB 13			6.0' SOUTH OF FB 13			9.1' SOUTH OF FB 13			17.9' SOUTH OF FB. 13		
COL NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO	MAX	SIMULT.	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT.	RATIO
1	7.10	1.80	1.02	7.00	1.70	1.02	7.20	1.60	1.01	7.40	1.50	1.05	7.30	1.70	1.04	6.90	1.90	0.93
2	6.20	3.30	0.89	6.90	3.20	1.00	6.30	2.90	0.88	6.70	3.40	0.95	6.60	2.70	0.94	6.80	1.90	0.91
3	6.50	1.90	0.94	6.70	2.70	0.97	6.10	1.90	0.85	6.30	2.80	0.89	6.50	1.80	0.92	7.00	1.20	0.94
4	6.50	3.90	0.94	7.00	3.30	1.02	6.00	3.00	0.84	7.10	3.20	1.00	7.10	3.10	1.01	7.00	3.70	0.94
5	7.30	3.30	1.05	6.90	3.60	1.00	6.60	2.70	0.92	7.00	3.90	0.99	7.60	2.90	1.08	7.40	3.70	0.99
6	6.40	3.30	0.92	6.00	3.80	0.87	5.90	3.20	0.82	6.60	3.90	0.93	6.60	3.20	0.94	7.20	3.00	0.97
7	6.40	3.70	0.92	6.90	3.70	1.00	6.90	3.50	0.97	7.20	3.60	1.02	6.60	3.70	0.94	7.80	4.00	1.05
8	6.90	3.60	0.99	6.90	3.10	1.00	6.80	2.40	0.95	6.60	3.10	0.93	5.10	2.70	0.72	6.90	3.90	0.93
9	6.60	3.20	0.95	6.30	4.10	0.92	6.50	3.30	0.91	6.50	4.30	0.92	6.70	3.70	0.95	7.90	2.90	1.06
10	6.50	3.80	0.94	6.70	3.70	0.97	6.60	3.50	0.92	5.90	3.70	0.83	6.10	3.90	0.87	7.10	2.60	0.95
11	6.60	4.40	0.95	7.30	5.10	1.06	7.70	4.50	1.08	7.00	5.90	0.99	6.70	5.20	0.95	7.70	3.50	1.03
12	7.10	5.70	1.02	7.70	6.60	1.12	8.00	6.70	1.12	7.40	6.80	1.05	7.60	6.90	1.08	7.60	5.70	1.02
13	8.00	8.00	1.15	6.90	6.90	1.00	8.10	8.10	1.13	7.30	7.30	1.03	7.60	7.60	1.08	7.90	7.90	1.06
14	7.30	7.30	1.05	6.20	5.60	0.90	6.50	6.00	0.91	6.70	4.90	0.95	7.30	6.70	1.04	7.80	6.50	1.05
15	6.70	5.70	0.97	6.20	3.90	0.90	6.60	4.10	0.92	6.80	2.90	0.96	6.60	5.20	0.94	7.30	6.20	0.98
16	7.70	4.10	1.11	7.00	3.10	1.02	8.30	2.80	1.16	8.00	2.10	1.13	7.40	3.30	1.05	7.50	6.00	1.01
17	6.70	2.30	0.97	6.50	1.60	0.94	7.20	1.40	1.01	6.80	1.10	0.96	7.00	1.90	0.99	7.10	3.60	0.95
18	7.30	1.10	1.05	7.20	0.60	1.05	6.80	0.50	0.95	7.30	0.50	1.03	8.00	0.80	1.13	7.50	2.30	1.01
19	7.60	0.40	1.10	7.40	0	1.07	9.20	0.20	1.28	7.70	0.20	1.09	7.90	0.30	1.12	7.90	1.20	1.06
20	7.30	0.10	1.05	7.40	0	1.07	8.70	0	1.22	7.60	0	1.07	7.40	0	1.05	7.40	0.30	0.99
21	6.80	0.20	0.98	6.60	0	0.96	6.60	0	0.92	6.70	0	0.95	7.50	0	1.06	7.20	0	0.97
22	6.90	0.10	0.99	6.60	0	0.96	7.40	0	1.03	6.80	0	0.96	8.00	0	1.13	8.00	0	1.07
23	6.70	0	0.97	6.90	0	1.00	7.40	0	1.03	6.80	0	0.96	6.80	0	0.97	7.80	0	1.05
24	7.60	0	1.10	8.30	0	1.21	8.70	0	1.22	8.40	0	1.19	7.20	0	1.02	8.50	0	1.14
AVERAGE	6.94			6.89			7.16			7.07			7.05			7.46		
STATIC *	8.40																	
DYNAMIC *	13.40																	

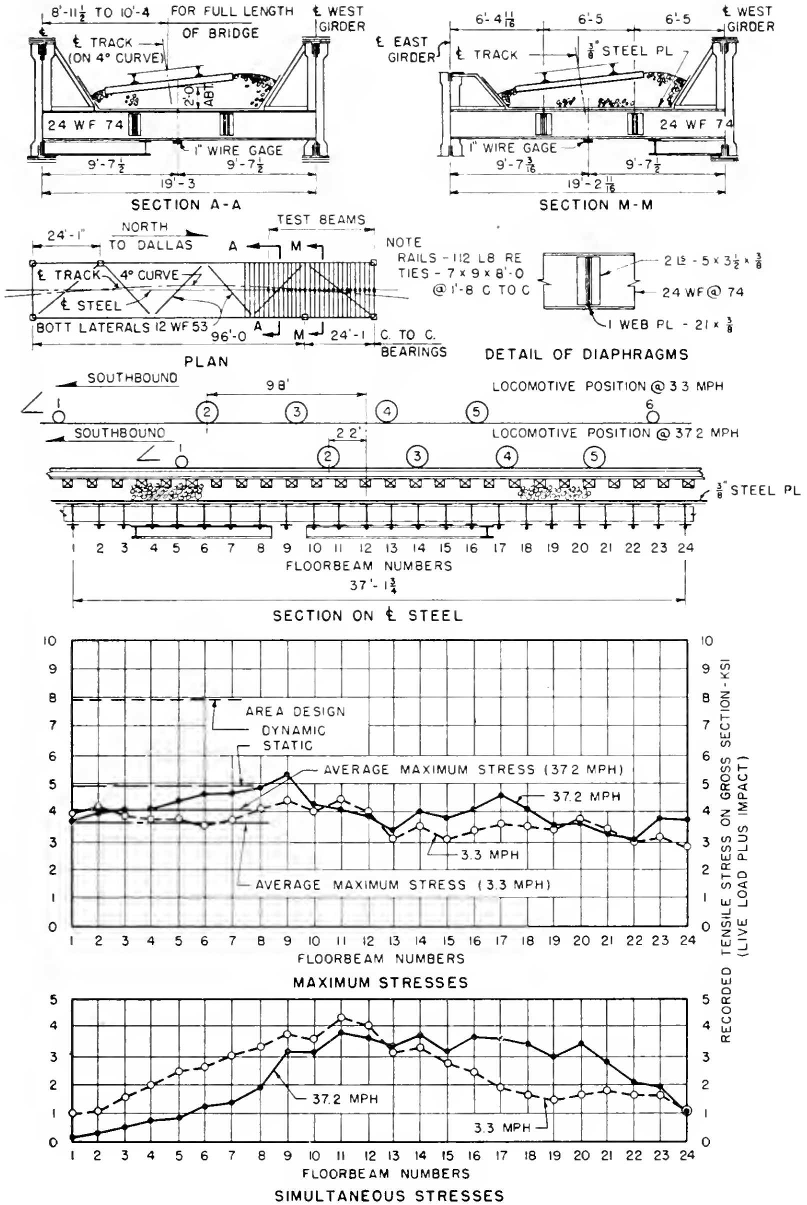
NOTE: STRESSES SHOWN ARE TENSION VALUES IN KSI.

"MAX." ARE MAXIMUM RECORDED STRESSES AT EACH FLOORBEAM

"SIMULT." SIMULTANEOUS STRESSES WITH MAXIMUM STRESS AT FLOORBEAM NO. 13

"RATIO" OF RECORDED MAXIMUM STRESS TO AVERAGE RECORDED MAXIMUM STRESS

* AREA DESIGN



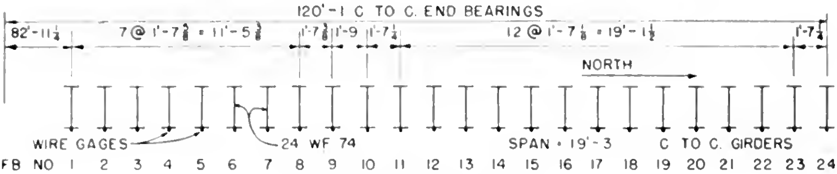
LOCOMOTIVES & SYMBOLS:
O RUN 6 – MKT 910 (2-8-2) @ 3.3 MPH SB
• RUN 17 – MKT 910 (2-8-2) @ 37.2 MPH SB

FOR TABULATION OF STRESSES, SEE FIGS 36 - 38 INCL.

FIG 35
M-K-T RR. BRIDGE TESTS
97'-2⅞ & 24'-4⅝ T.P.G. SPANS
BALLASTED STEEL PLATE FLOOR
LOCATION OF GAGES AND TYPICAL RECORDED STRESSES IN TRANSVERSE FLOORBEAMS

FIG 36
MISSOURI - KANSAS - TEXAS RAILROAD BRIDGE TESTS
97'-2$\frac{1}{4}$ & 24'-4$\frac{3}{4}$ THROUGH GIRDER SPANS — BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



SECTION ON ℄ BETWEEN GIRDERS

TEST TRAIN	SOUTHBOUND						NB			SOUTHBOUND									NB		
	2 - AXLE DIESEL									LOCOMOTIVE TYPE 3 - AXLE DIESEL											
	RI 103			MKT 332			RI 119			MKT 154			CB&Q 9948			RI 632			MKT 107		
RUN NO.	4			3			5			15			2			16			1		
SPEED IN MPH	35			56			28.9			11.0			49.9			52.2			53.1		
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST WHEEL AT																				
	81.7' SOUTH OF ℄ FB. 12			77.0' SOUTH OF ℄ FB. 12			112.6' SOUTH OF ℄ FB 12			34.3' SOUTH OF ℄ FB. 12			48.1' SOUTH OF ℄ FB 12			111.0' SOUTH OF ℄ FB 12			59.8' SOUTH OF ℄ FB. 12		
COL. NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
FLOOR-BEAM NO.	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT	RATIO
1	2.65	0.35	1.02	2.60	0.65	1.02	2.35	1.40	0.99	2.25	0.45	1.06	2.70	0.10	1.02	2.45	-.30	0.99	2.55	2.15	0.96
2	2.80	0.40	1.07	2.75	0.55	1.07	2.40	0.95	1.01	2.30	0.40	1.08	2.70	0.20	1.02	2.55	-.20	1.03	2.65	2.00	0.99
3	2.40	0.45	0.92	2.30	0.60	0.90	2.20	0.65	0.93	2.05	0.40	0.96	2.35	0.10	0.88	2.45	-.10	0.99	2.50	1.90	0.94
4	2.45	0.60	0.94	2.40	0.75	0.94	2.25	0.50	0.95	2.00	0.50	0.94	2.40	0.20	0.90	2.50	0.10	1.01	2.50	1.90	0.94
5	2.65	0.90	1.02	2.65	1.05	1.04	2.45	0.25	1.03	2.05	0.60	0.96	2.75	0.30	1.03	2.65	0.20	1.07	2.75	2.00	1.03
6	2.70	1.25	1.03	2.75	1.55	1.07	2.40	0.35	1.01	2.15	1.00	1.01	2.70	0.45	1.02	2.75	0.45	1.11	2.75	1.60	1.03
7	2.65	1.85	1.02	2.60	1.95	1.02	2.55	0.40	1.08	2.25	1.60	1.06	2.70	0.90	1.02	2.70	1.05	1.09	2.85	1.35	1.07
8	2.85	2.10	1.09	2.90	2.20	1.13	2.65	0.60	1.12	2.30	1.85	1.08	2.75	1.50	1.03	2.80	1.75	1.13	2.90	1.30	1.09
9	3.60	2.45	1.38	3.65	2.60	1.42	3.50	1.45	1.48	2.70	2.15	1.27	4.00	2.90	1.50	3.40	2.75	1.37	3.70	1.95	1.39
10	2.85	1.85	1.09	2.80	1.85	1.09	2.60	1.85	1.10	2.35	1.75	1.10	2.70	2.15	1.02	2.80	2.20	1.13	2.85	1.60	1.07
11	3.05	2.20	1.17	2.95	2.00	1.15	2.75	2.50	1.16	2.45	1.95	1.15	3.00	2.30	1.13	2.70	2.20	1.09	3.00	2.10	1.12
12	2.60	2.30	1.00	2.55	2.25	1.00	2.35	2.25	0.99	2.25	2.10	1.06	2.55	2.15	0.96	2.65	2.00	1.07	2.55	2.15	0.96
13	2.30	2.30	0.88	2.20	2.20	0.86	2.00	2.00	0.84	1.80	1.80	0.85	2.50	2.50	0.94	2.05	2.05	0.83	2.80	2.80	1.05
14	2.40	2.00	0.92	2.40	2.10	0.94	2.05	1.80	0.87	1.95	1.75	0.92	2.40	2.40	0.90	2.20	2.10	0.89	2.30	2.20	0.86
15	2.10	1.45	0.80	2.10	1.55	0.82	1.95	1.40	0.82	1.75	1.50	0.82	2.40	2.10	0.90	2.05	1.75	0.83	3.30	1.95	1.24
16	2.20	1.35	0.84	2.35	1.30	0.92	2.15	1.60	0.91	2.05	1.80	0.96	1.85	1.60	0.70	2.35	1.95	0.95	1.80	1.65	0.67
17	2.50	1.45	0.96	2.50	0.95	0.98	2.35	2.20	0.99	2.10	2.00	0.99	2.80	2.65	1.05	2.50	2.00	1.01	2.75	2.60	1.03
18	2.45	1.70	0.94	2.45	0.80	0.96	2.35	2.10	0.99	2.25	1.80	1.06	2.75	2.25	1.03	2.45	1.80	0.99	2.75	2.50	1.03
19	2.45	1.95	0.94	2.40	0.80	0.94	2.65	1.80	1.12	2.05	1.30	0.96	2.70	1.75	1.02	2.30	1.25	0.93	2.80	2.40	1.05
20	2.70	2.25	1.03	2.65	0.70	1.04	2.50	1.60	1.05	2.25	1.10	1.06	2.90	1.40	1.09	2.55	1.00	1.03	2.80	2.35	1.05
21	2.45	1.90	0.94	2.35	0.80	0.92	2.15	1.35	0.91	2.00	0.70	0.94	2.70	1.05	1.02	2.30	0.70	0.93	2.55	2.20	0.96
22	2.30	1.55	0.88	2.20	0.50	0.86	2.00	1.30	0.84	1.75	0.50	0.82	2.45	0.60	0.92	2.05	0.30	0.83	2.20	1.70	0.82
23	3.15	1.80	1.21	2.60	0.65	1.02	2.20	1.50	0.93	2.15	0.65	1.01	2.65	0.45	1.00	2.35	0.20	0.95	2.25	1.30	0.84
24	2.50	1.65	0.96	2.45	0.40	0.96	2.15	1.85	0.91	1.95	0.50	0.92	2.40	0	0.90	2.15	-.10	0.87	2.20	0.35	0.82
AVERAGE	2.61			2.56			2.37			2.13			2.66			2.48			2.67		
STATIC *	2.96			2.99			2.96			3.16			3.70			3.44			3.62		
DYNAMIC *	4.15			4.20			4.15			4.44			5.18			4.83			5.09		

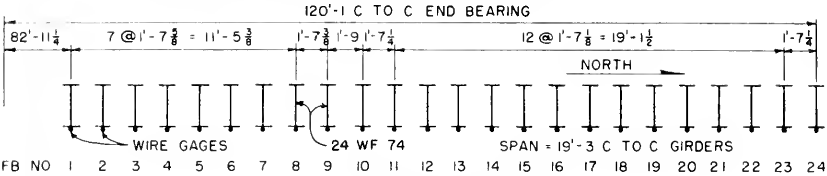
NOTE STRESSES SHOWN ARE TENSION VALUES IN KSI.
"MAX." ARE MAXIMUM RECORDED STRESSES AT EACH FLOORBEAM.
"SIMULT" - SIMULTANEOUS STRESS WITH MAXIMUM STRESS AT FLOORBEAM 13.
"RATIO" OF RECORDED MAXIMUM STRESS TO AVERAGE RECORDED MAXIMUM STRESS.
* AREA DESIGN
- INDICATES COMPRESSION

FIG 37

MISSOURI - KANSAS - TEXAS RAILROAD BRIDGE TESTS

97'-2 7/8 & 24'-4 5/8 THROUGH GIRDER SPANS - BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



SECTION ON ℄ BETWEEN GIRDERS

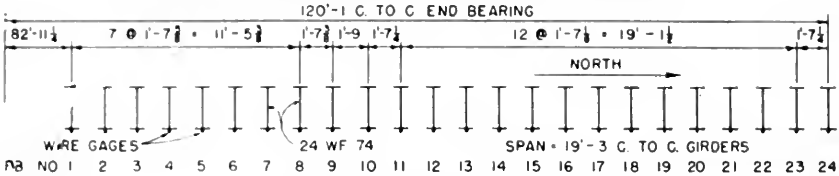
TEST TRAIN	SOUTHBOUND, LOCOMOTIVE TYPE 2-8-2, MKT 910																				
RUN NO	6			19			7			18			8			13			11		
SPEED IN MPH	3 3			3 4			3 7			3 9			17 4			19 2			19.7		
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST DRIVER AT 9 8' SOUTH OF ℄ FB. 12			7 5' SOUTH OF ℄ FB 12			4 7' SOUTH OF ℄ FB 12			2 5' SOUTH OF ℄ FB 12			7 0' SOUTH OF ℄ FB 12			10 1' SOUTH OF ℄ FB 12			8 3' SOUTH OF ℄ FB 12		
COL NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
FLOOR-BEAM NO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX.	SIMULT.	RATIO	MAX	SIMULT	RATIO
1	3.95	100	109	3 85	0.70	108	3 60	065	1.04	3 65	080	109	3 75	075	106	3 75	1 15	103	3 90	095	107
2	4 15	105	114	3.80	070	107	365	075	105	370	085	110	3 80	085	108	3 90	135	107	370	095	102
3	385	155	106	350	105	099	340	095	098	350	105	104	360	100	102	385	1.90	106	355	120	097
4	375	200	103	355	140	100	375	115	108	370	130	110	365	130	103	410	260	1.13	390	165	107
5	375	245	103	355	185	100	380	155	110	355	180	106	385	175	109	395	320	108	380	220	105
6	355	265	098	380	235	107	380	195	110	375	225	112	400	210	113	365	325	100	390	255	107
7	370	300	102	375	275	106	385	260	111	390	275	116	425	260	120	390	360	107	405	290	111
8	410	335	113	385	290	108	415	300	120	410	305	122	410	270	116	390	380	107	410	310	113
9	435	375	120	440	355	124	440	330	127	440	355	131	455	320	129	435	420	120	455	375	125
10	400	355	110	390	330	110	375	325	108	365	335	109	425	310	1.20	400	395	110	425	355	117
11	440	435	121	400	355	113	390	360	112	395	365	118	425	340	120	440	440	121	405	380	111
12	400	400	110	370	340	104	335	320	097	350	325	104	350	320	099	395	395	108	360	345	099
13	310	310	085	310	310	087	295	295	085	270	270	080	300	300	085	295	295	081	285	285	078
14	355	325	098	325	325	092	340	335	098	310	300	092	345	335	098	340	330	093	335	305	092
15	310	275	085	300	275	085	290	275	084	290	265	086	330	285	093	315	280	087	310	260	085
16	335	250	092	345	290	097	350	300	101	330	275	0.98	370	300	105	360	260	099	365	270	100
17	360	190	099	350	250	099	350	270	101	320	2.40	095	375	2.75	1.06	335	180	092	365	225	100
18	350	165	096	350	210	099	335	235	097	310	205	092	380	225	108	345	155	095	380	180	105
19	335	145	092	340	160	096	325	185	094	295	150	088	355	170	101	350	140	096	380	150	105
20	375	165	1.03	375	155	1.06	350	160	101	325	135	097	410	170	1.16	390	1.50	107	395	140	108
21	340	1.80	094	330	150	093	310	140	089	290	130	086	335	165	095	330	160	091	325	135	089
22	305	1.65	084	310	165	0.87	280	125	081	260	120	077	295	160	083	300	145	082	280	135	077
23	3.15	160	087	335	200	094	305	160	088	280	160	083	345	220	0.98	3.10	1.30	085	325	165	089
24	285	110	078	275	180	077	260	1.65	075	250	175	074	310	200	088	295	085	081	265	135	073
AVERAGE	364			355			347			336			353			364			364		
STATIC	5 06			5 06			5 06			5 06			5 06			5.06			5 06		
DYNAMIC	8 14			8 14			8 14			8 14			8 14			8.14			8 14		

FOR NOTES SEE FIG 36

A

FIG 38
MISSOURI-KANSAS-TEXAS RAILROAD BRIDGE TESTS
97'-2¼ & 24'-4¾ THROUGH GIRDER SPANS - BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



SECTION ON ℄ BETWEEN GIRDERS

TEST TRAIN	SOUTHBOUND																	
	LOCOMOTIVE TYPE: 2-8-2															4-0-4		
	MKT 910															MKT 1506		
RUN NO	9			10			14			12			17			20		
SPEED IN MPH	21.7			24.4			32.6			33.1			37.2			41.9		
LOCOMOT POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT															1ST WHEEL AT		
	7.8' SOUTH OF ℄ FB 12			8.0' SOUTH OF ℄ FB. 12			5.0' SOUTH OF ℄ FB. 12			7.9' SOUTH OF ℄ FB. 12			2.2' SOUTH OF ℄ FB. 12			26.7' SOUTH OF ℄ FB. 12		
COL. NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
FLOOR-BEAM NO.	MAX	SIMULT	RATIO	MAX	SIMULT	RATIO	MAX.	SIMULT	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
1	3.90	0.80	1.05	4.10	0.60	1.03	3.55	0.30	0.92	4.60	0.70	1.15	3.70	0.15	0.92	1.35	0.70	0.62
2	4.10	0.80	1.10	4.75	0.70	1.20	3.70	0.50	0.96	4.60	0.65	1.15	3.95	0.30	0.98	1.45	0.10	0.67
3	3.90	1.05	1.05	4.25	1.00	1.07	3.70	0.70	0.96	4.20	1.00	1.05	4.05	0.50	1.00	1.60	0	0.73
4	3.60	1.50	0.97	4.05	1.40	1.02	3.95	0.80	1.03	4.05	1.35	1.01	4.05	0.75	1.00	2.25	0.35	1.03
5	3.50	2.00	0.94	4.20	2.00	1.06	4.60	1.20	1.20	3.95	1.80	0.98	4.35	0.90	1.08	2.50	0.10	1.15
6	3.70	2.40	0.99	4.20	2.50	1.06	4.40	1.30	1.15	3.75	2.25	0.93	4.60	1.20	1.14	2.75	0.25	1.26
7	3.80	2.65	1.02	4.10	2.90	1.03	4.15	1.75	1.08	3.75	2.50	0.93	4.65	1.35	1.15	2.40	0.35	1.10
8	4.00	3.00	1.07	3.95	3.10	0.99	4.50	2.30	1.17	4.15	2.75	1.03	4.85	1.90	1.20	2.60	0.50	1.19
9	4.55	3.60	1.22	4.50	3.60	1.13	5.10	3.10	1.32	4.85	3.55	1.21	5.35	3.10	1.33	3.05	0.80	1.40
10	4.20	3.40	1.15	4.10	3.35	1.03	4.10	2.70	1.07	4.75	3.30	1.18	4.25	3.10	1.05	2.50	0.60	1.15
11	4.40	3.65	1.18	4.80	3.50	1.21	4.10	3.10	1.07	5.25	3.70	1.31	4.05	3.80	1.00	2.70	1.30	1.24
12	4.00	3.45	1.07	4.45	3.30	1.12	3.70	2.90	0.96	4.30	3.60	1.07	3.90	3.60	0.97	2.35	1.50	1.08
13	3.00	3.00	0.80	3.50	3.50	0.88	3.20	3.20	0.83	3.40	3.40	0.85	3.35	3.35	0.83	1.90	1.90	0.87
14	3.45	3.35	0.92	3.95	3.80	0.99	3.85	3.85	1.00	3.70	3.70	0.92	4.00	3.75	0.99	2.10	1.85	0.96
15	3.10	2.90	0.83	3.50	3.20	0.88	3.70	3.70	0.96	3.30	3.20	0.82	3.80	3.15	0.94	1.95	1.60	0.90
16	3.60	3.00	0.87	3.60	3.45	0.91	3.85	3.70	1.00	3.55	3.10	0.88	4.05	3.70	1.00	1.95	1.50	0.90
17	3.75	2.45	1.01	3.40	3.05	0.86	4.40	3.25	1.15	3.50	2.50	0.87	4.60	3.55	1.14	2.35	1.90	1.08
18	3.60	1.95	0.87	3.50	2.45	0.88	4.00	2.55	1.04	3.55	1.85	0.88	4.05	3.40	1.00	2.40	2.00	1.10
19	3.50	1.50	0.94	3.50	2.00	0.88	3.25	1.85	0.85	3.65	1.30	0.91	3.55	3.00	0.88	2.40	2.05	1.10
20	4.05	1.50	1.09	4.00	1.95	1.01	3.45	1.60	0.90	4.35	1.25	1.08	3.65	3.45	0.90	2.55	1.90	1.17
21	3.65	1.55	0.98	3.90	2.00	0.98	3.10	1.25	0.81	3.85	1.35	0.96	3.25	2.80	0.81	2.30	1.30	1.06
22	3.35	1.65	0.90	3.55	1.95	0.89	3.00	0.95	0.78	3.60	1.40	0.90	3.10	2.10	0.77	1.25	0.60	0.57
23	3.70	2.10	0.99	3.80	2.45	0.96	3.50	1.30	0.91	4.10	1.80	1.02	3.75	1.95	0.93	1.95	0.55	0.90
24	3.10	1.75	0.83	3.55	2.05	0.89	3.35	1.35	0.87	3.55	1.80	0.88	3.70	1.10	0.92	1.85	1.20	0.85
AVERAGE	3.73			3.97			3.84			4.01			4.03			2.18		
STATIC	5.06			5.06			5.06			5.06			5.06			3.12		
DYNAMIC	8.14			8.14			8.14			8.14			8.14			4.37		

FOR NOTES SEE FIG 36

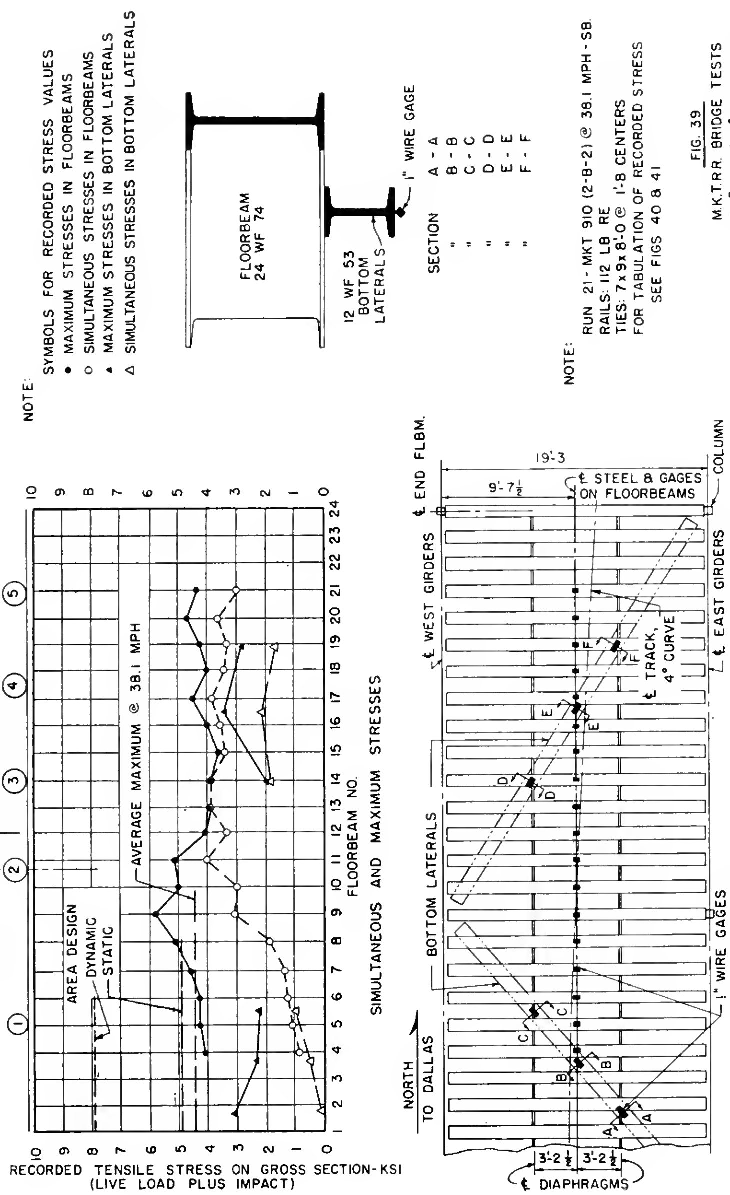


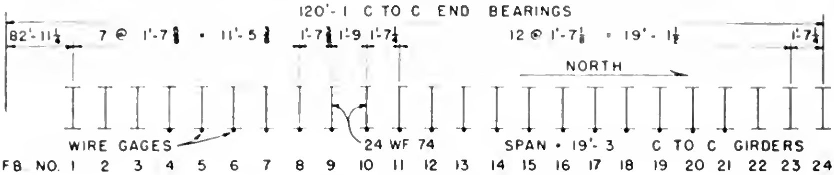
FIG. 39
M.K.T.R.R. BRIDGE TESTS
97'-2⅞ & 24'-4⅜ T.P.G. SPANS
BALLASTED STEEL PLATE FLOOR
LOCATION OF GAGES AND TYPICAL RECORDED STRESSES IN TRANSVERSE FLOORBEAMS AND LATERALS

FIG 40

MISSOURI - KANSAS - TEXAS RAILROAD BRIDGE TESTS

97'-2 3/8 & 24'-4 3/8 THROUGH GIRDER SPANS - BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



SECTION ON ℄ BETWEEN GIRDERS

TEST TRAIN	NORTHBOUND						SOUTHBOUND														
	2-AX. DIESEL			3-AX DIESEL			LOCOMOTIVE TYPE - 2-8-2														
	MKT 333			FRISCO 2018			MKT 910														
RUN NO	22			34			33			32			25			26			24		
SPEED IN MPH	42 8			47 6			4 6			5.0			5 1			5.2			5 7		
LOCOMOT. POSITION FOR SIMULTAN STRESS	FIRST WHEEL AT						FIRST DRIVER AT														
	118' NORTH OF ℄ FB 12			76.7' NORTH OF ℄ FB 12			12.5' SOUTH OF ℄ FB 12			5.9' SOUTH OF ℄ FB 12			10.0' SOUTH OF ℄ FB 12			2 5' SOUTH OF ℄ FB. 12			8.3' SOUTH OF ℄ FB. 12		
COL NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
FLOOR-BEAM NO	MAX.	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
4	2 45	1 00	0 97	2 40	0 60	0 87	3 75	1 80	0.97	3 75	1 05	1 03	3 90	1 60	1.07	3.90	0.90	1.05	3.80	1.60	1.03
5	2 65	0 60	1 05	2 60	0.85	0.94	3 55	2 25	0.92				3 95	2.15	1.08	3.95	1.10	1 06	3.85	2 25	1.04
6	2.75	0.70	1.09	2.80	1.65	1 01	3.60	2.50	0.93	3.95	1 35	1 09	3 80	2.50	1.04	4 05	1.15	1.09	3.95	2.65	1.07
7	2.60	0 65	1 03	3 00	1.75	1.08	3 85	2 70	1.00	4 00	1 85	1.10	3.75	2.55	1.03	4.10	1 50	1.10	4 00	2.95	1.08
8	2.70	0.85	1 07	3 30	2.50	1.19	3.95	3.10	1.02	4 05	2.50	1.11	4 10	2 95	1 12	4 25	2 00	1.14	4.30	3.25	1.17
9	3.15	1. 35	1.25	4 15	3.60	1 50	4.35	3 50	1.13	4.55	3.40	1.25	4.70	3 60	1.29	4 55	3.00	1.22	4.20	3.80	1.14
10	2 70	1 45	1 07	2 85	2.55	1 03	4 15	3 45	1.08	4 00	3 05	1.10	4 00	3.35	1.10	4 00	3.00	1.07	3.90	3.60	1.06
11	3 05	2.10	1.21	2.95	2.50	1.07	4.80	4.30	1.24	4 20	3 45	1.15	4.55	4 00	1.25	4.05	3.40	1.09	4.25	3.85	1.15
12	2.30	2.30	0.91	2.80	2.50	1 01	4 10	4.10	1.06	3.55	3.20	0.97	4.05	4 05	1.11	3.45	3.10	0.93	3.55	3.35	0.96
13	2.35	2.35	0.93	2.15	2 15	0.78	4 10	4.10	1.06	3.40	3 40	0.93	3.55	3.55	0.97	3.20	3.20	0.86	3.20	3.20	0.87
14	2 20	2.00	0 87	2.55	2 20	0 92	3 50	3.30	0.91	3.10	2.90	0.85	3.60	3.35	0.99	3.30	3.15	0.89	3.20	3.20	0.87
15	1 85	1.60	0.73	2 45	2.00	0 89	3.20	2.75	0 83	2.90	2.90	0.80	3.20	2.95	0.88	3.15	3.00	0.85	3 05	2.75	0.83
16	2 40	1.55	0.95	2.50	1 95	0 90	3.85	2.90	1.00	3.55	3.55	0.97	3.80	3.00	1.04	3.65	3.60	0.98	3.60	3.00	0.98
17	2 45	1 75	0.97	2.75	2.20	0 99	3.65	2.10	0.95	3.35	3 00	0.92	3.70	2.25	1.01	3.55	3.40	0.95	3.55	2.60	0.96
18	2.35	1 85	0.93	2.75	1.95	0.99	3 40	1.65	0.88	3 25	2.70	0.89	3.65	1 80	1.00	3.40	3.10	0.91	3.45	2.00	0.94
19	2 60	1.65	1 03	2.75	1.45	0.99	3.45	1.40	0.89	3.25	2.50	0.89	3.55	1.50	0.97	3.45	2.90	0.93	3.35	1.60	0.91
20	2 60	1 40	1.03	2 75	1 05	0 99	4 20	1.65	1.09	3.70	2.50	1.02	3 95	1.60	1.08	3.75	3.10	1.01	3.70	1.45	1.00
21	2.15	0.70	0 85	2 25	0.80	0.81	4 00	1.90	1.04	3.30	1.90	0.91	3.70	1.80	1.01	3.40	2.45	0.91	3.40	1.50	0.92
AVERAGE	2 52			2.77			3.86			3.64			3.65			3.73			3.69		
STATIC	2 99						5.06			5.06			5.06			5.0 6			5.06		
DYNAMIC	4.20						8.14			8. 14			8 14			8 14			8.14		

SECTION▲	STRESSES IN BOTTOM LATERALS																				
A-A	-1 10	0 40		-1.35	-.60		2.40	0 20		2 25	0 20		2 25	0.15		2 25	0 30		2.25	0.35	
B-B	1.35	0		-1 20	-.40		2 25	0.70		2.20	0 65		2.30	0.60		2 40	0 80		2.30	0.65	
C-C	1.60	-.60		-1.50	0.20		1.95	1.70		2.25	1.15		1 85	1.65		2.30	1.20		2.20	1.80	
D-D	-.75	-.20		-1.30	0.20		1.45	1.30		1.00	0.75		1.70	1.30		1.05	0.90		1.05	0.90	
E-E	1.30	0		-1.45	0.60		2.60	1.20		2.00	1.90		2.60	1.30		2.10	1.85		2.05	1.35	
F-F	1.70	0.30		1.70	-.30		2.50	-.10		2.40	1.30		2.55	-.20		2.30	1.50		2.15	-.10	
AVERAGE	0 68			-.85			2.19			2.02			2.04			2.07			2.00		

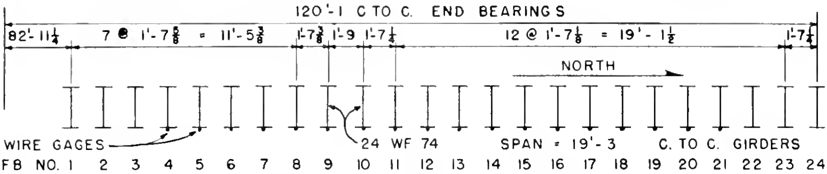
NOTE: NOTES ON FIG. 36 APPLY FOR FIG. 40 AND FIG. 41
▲ SEE FIG. 39 FOR LOCATION OF THESE SECTIONS
— INDICATES COMPRESSION

FIG. 41

MISSOURI - KANSAS - TEXAS RAILROAD BRIDGE TESTS

97'-2⅞ & 24'-4⅝ THROUGH GIRDER SPANS - BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN TRANSVERSE FLOORBEAMS



SECTION ON ℄ BETWEEN GIRDERS

TEST TRAIN	SOUTHBOUND LOCOMOTIVE TYPE : 2-8-2 MKT 910																				
RUN NO.	28			31			27			30			29			21			23		
SPEED IN MPH	15.1			20.0			20.6			25.4			28.8			38.1			42.2		
LOCOMOT. POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT 5.3' SOUTH OF ℄ FB. 12			8.9' SOUTH OF ℄ FB. 12			10.1' SOUTH OF ℄ FB. 12			8.7' SOUTH OF ℄ FB. 12			10.3' SOUTH OF ℄ FB. 12			2.1' SOUTH OF ℄ FB. 12			10.4' SOUTH OF ℄ FB. 12		
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
FLOOR-BEAM NO.	MAX	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO	MAX.	SIMULT.	RATIO
4	3.65	0.90	0.99	3.95	1.55	1.02	3.50	1.90	0.89	3.95	1.60	1.05	4.10	1.95	1.00	4.05	0.85	0.92	4.60	1.25	1.05
5	3.85	1.15	1.05	3.90	2.05	1.01	3.75	2.30	0.96	3.60	2.25	0.96				4.25	1.05	0.96	4.70	1.50	1.07
6	3.90	1.05	1.06	3.95	2.55	1.02	3.95	2.55	1.01	3.65	2.80	0.97	4.00	2.75	0.97	4.25	1.20	0.96	4.45	1.90	1.02
7	3.90	1.30	1.06	3.95	2.85	1.02	4.15	2.90	1.06	3.70	3.10	0.98	3.85	3.00	0.94	4.55	1.30	1.03	4.45	2.55	1.02
8	4.00	1.65	1.09	3.85	3.30	0.99	4.40	3.35	1.13	4.10	3.35	1.09	4.20	3.30	1.02	5.10	1.90	1.16	4.70	3.30	1.07
9	4.40	2.65	1.20	4.50	4.10	1.16	4.75	3.90	1.22	4.45	4.05	1.18	4.70	4.10	1.14	5.80	3.10	1.32	5.35	4.20	1.22
10	3.70	2.80	1.01	4.15	3.85	1.07	4.20	3.55	1.07	4.10	3.65	1.09	4.50	3.90	1.10	5.00	3.00	1.13	4.00	3.65	0.91
11	4.15	3.50	1.13	4.50	4.45	1.16	4.70	4.25	1.20	4.75	4.00	1.26	4.75	4.65	1.16	5.15	4.00	1.17	4.60	4.15	1.05
12	3.45	3.05	0.94	4.05	4.05	1.04	4.05	4.05	1.04	3.75	3.60	0.99	4.40	4.40	1.07	4.05	3.35	0.92	4.15	3.35	0.95
13	3.20	3.20	0.87	3.65	3.65	0.94	3.35	3.35	0.86	3.35	3.35	0.89	3.70	3.70	0.90	3.85	3.85	0.87	4.15	4.15	0.95
14	3.25	3.25	0.88	3.65	3.40	0.94	3.20	2.95	0.82	3.30	3.30	0.88	3.65	3.55	0.89	3.85	3.85	0.87	4.50	4.50	1.03
15	3.10	3.05	0.84	3.40	2.80	0.88	3.20	2.70	0.82	3.15	2.80	0.83	3.50	3.35	0.85	3.60	3.40	0.82	4.00	4.00	0.91
16	3.75	3.60	1.02	3.85	2.95	0.99	3.90	2.70	1.00	3.60	3.00	0.96	3.70	3.30	0.90	4.00	3.55	0.91	4.50	3.85	1.03
17	3.55	3.45	0.96	3.60	2.25	0.93	3.70	1.90	0.95	3.50	2.45	0.93	3.70	2.25	0.90	4.50	3.85	1.02	4.60	3.25	1.05
18	3.60	3.35	0.98	3.55	1.75	0.92	3.70	1.65	0.95	3.55	1.85	0.94	3.85	1.80	0.94	4.00	3.45	0.91	4.45	2.50	1.02
19	3.55	3.10	0.96	3.45	1.35	0.89	3.65	1.50	0.93	3.50	1.35	0.93	3.95	1.45	0.91	4.25	3.35	0.96	4.05	1.80	0.92
20	3.75	3.35	1.02	4.05	1.35	1.04	4.25	1.80	1.09	4.00	1.30	1.06	4.65	1.70	1.13	4.70	3.65	1.07	4.05	1.55	0.93
21	3.45	2.95	0.94	3.85	1.60	0.99	4.00	2.05	1.02	3.80	1.40	1.01	4.45	1.85	1.08	4.35	3.00	0.98	3.55	1.20	0.81
AVERAGE	3.68			3.88			3.91			3.77			4.11			4.41			4.38		
STATIC	5.06			5.06			5.06			5.06			5.06			5.06			5.06		
DYNAMIC	8.14			8.14			8.14			8.14			8.14			8.14			8.14		

SECTION ▲	STRESSES IN BOTTOM LATERALS																				
A-A	2.05	0.15		2.40	0.30		2.15	0.10		2.15	0.40		3.05	0.10		2.70	0.10		2.30	0	
B-B	2.25	0.70		2.40	0.50		2.05	0.70		2.50	0.60		2.40	0.70		2.35	0.45		2.70	0.50	
C-C	2.55	1.30		2.15	1.65		2.15	1.60		2.50	1.90		2.20	1.90		2.35	0.95		2.05	1.05	
D-D	1.05	1.05		1.75	1.45		1.65	1.40		1.30	1.30		1.90	1.75		1.80	1.80		2.50	2.20	
E-E	2.10	1.95		2.60	1.25		2.50	1.25		2.05	1.35		2.45	1.30		3.40	2.10		3.10	1.70	
F-F	2.60	1.70		2.25	-.35		2.40	0.10		2.30	-.20		2.65	0.10		2.85	1.65		3.00	0	
AVERAGE	2.10			2.26			2.15			2.13			2.44			2.58			2.61		

NOTE: ▲ SEE FIG. 39 FOR LOCATION OF THESE SECTIONS,
- INDICATES COMPRESSION

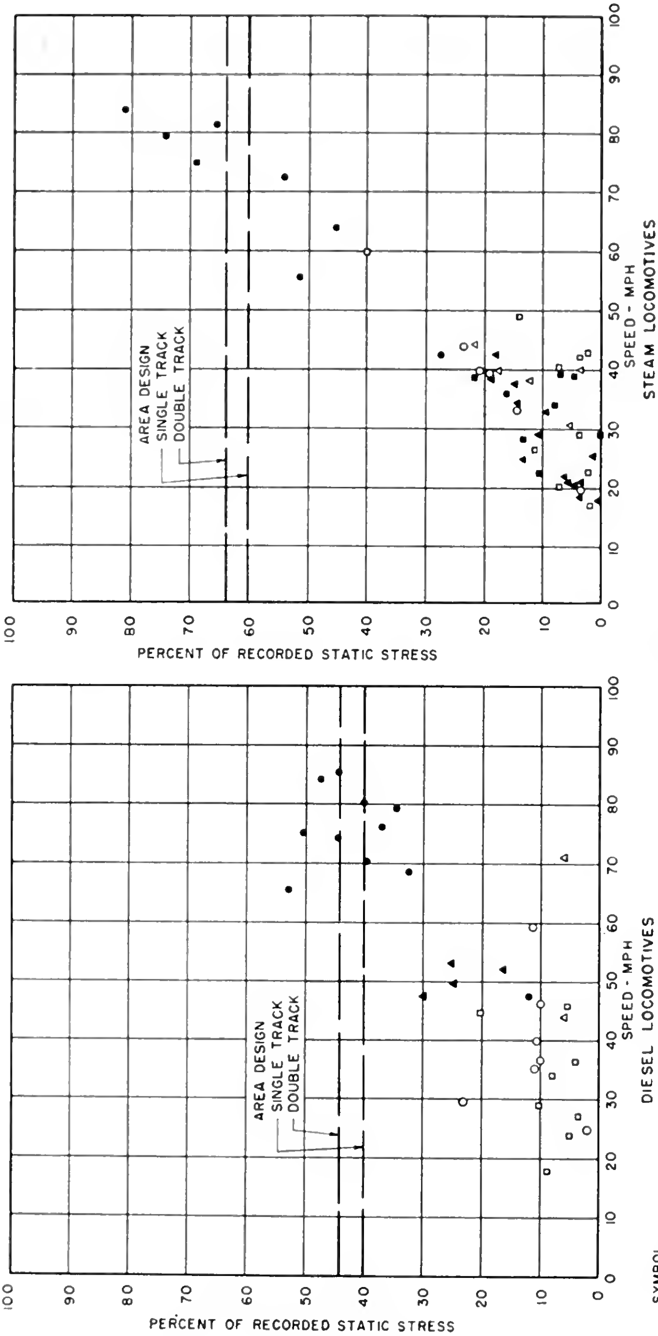


FIG. 42

TOTAL IMPACTS IN TRANSVERSE FLOORBEAMS

DIESEL AND STEAM LOCOMOTIVES

TOTAL IMPACTS

NOTE AREA DESIGN FOR SINGLE TRACK BRIDGES DOES NOT INCLUDE ROLL EFFECT DUE TO THE PROXIMITY OF THE GAGE TO THE ℄ OF THE TRACK

SYMBOL

SINGLE TRACK
- □ NYC 70'-0 (13'-6, 12 I @ 70, 2'-1½)
- ● NYC 39'-0¼ (11'-3, 15 I @ 50, 1'-4⅜)
- ○ SOU 58'-4½ (17'-6, 18 WF @ 85, 1'-11¾)
- ▲ MKT 97'-2⅞ (19'-3, 24 WF @ 74, 1'-7⅜)

DOUBLE TRACK
- △ B&O 74'-7⅜ (31'-8, 30 WF @ 172, 2'-10¾)
- ■ NYC 93'-5 (30'-6, 28¼ BG @ 175, 1'-10½)

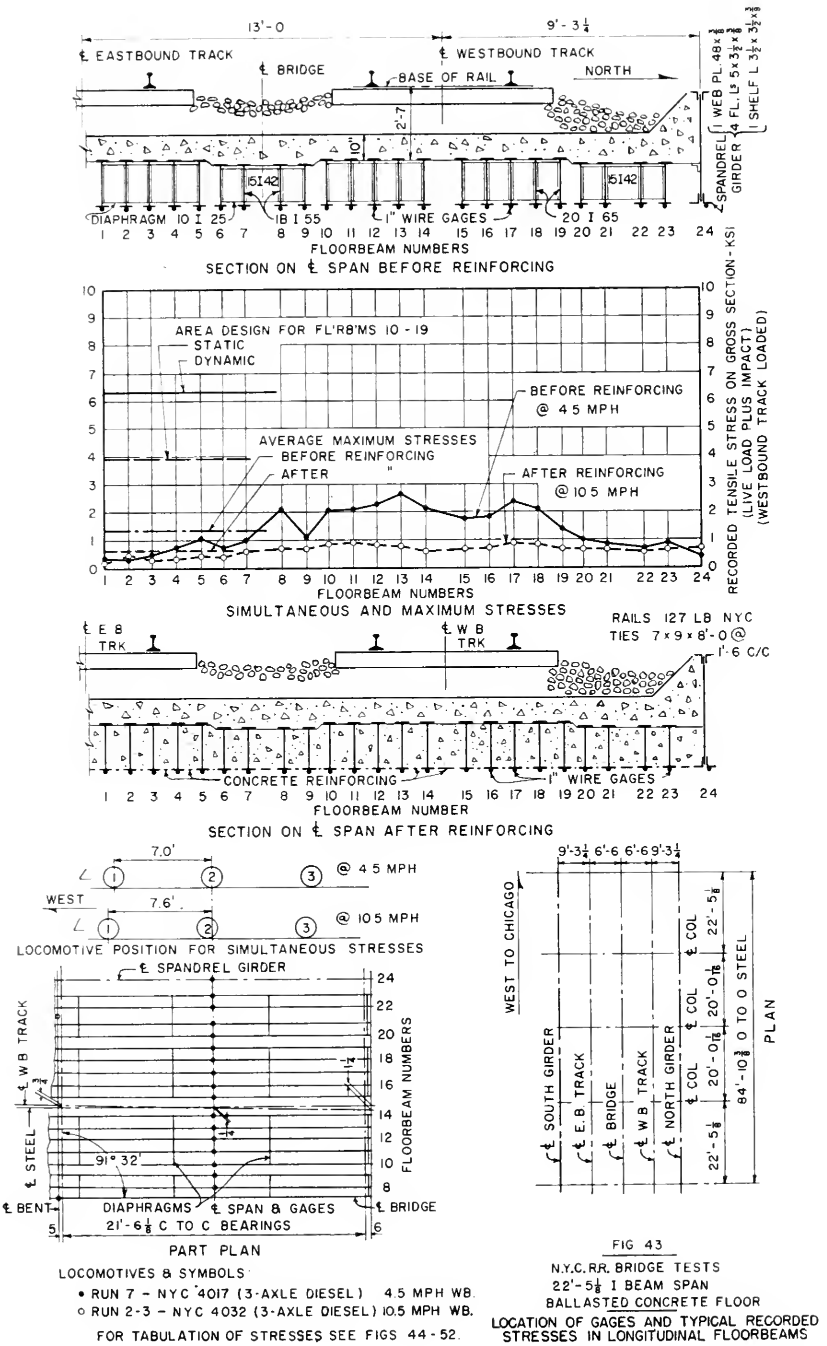


FIG 43

N.Y.C.RR. BRIDGE TESTS
22'-5⅛ I BEAM SPAN
BALLASTED CONCRETE FLOOR
LOCATION OF GAGES AND TYPICAL RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS

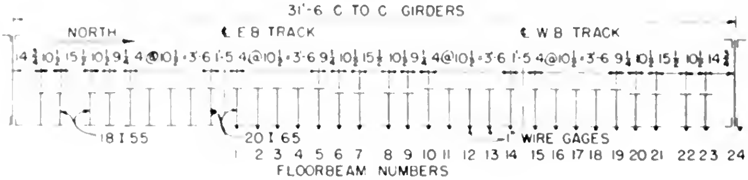
FIG 44

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

22'-5 I BEAM SPAN - BALLASTED CONCRETE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS

31'-6 C TO C GIRDERS



SECTION PERPENDICULAR TO ℄ OF TRACK

TEST TRAIN	BEFORE REINFORCING															
	WESTBOUND															
	2-AXLE DIESEL				LOCOMOTIVE TYPE 3 AXLE DIESELS											
	C & O 5211				NYC 4017				NYC 4200				NYC 4027			
RUN NO	5				7				9				3			
SPEED IN MPH	5 EST				45				48				590			
LOCOMOT POSITION FOR SIMULTAN STRESS	FIRST WHEEL AT															
					70' WEST OF ℄ SPAN				8.1' WEST OF ℄ SPAN				100' WEST OF ℄ SPAN			
COL NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOOR-BEAM NO	SIMULT	TIME LAG	MAX	RATIO	SIMULT	TIME LAG	MAX	RATIO	SIMULT	TIME LAG	MAX	RATIO	SIMULT	TIME LAG	MAX	RATIO
1	0.35	0	0.35	0.26	0.35	0	0.35	0.26	0.35	0	0.35	0.29	0.25	0.02	0.50	0.30
2	0.30	0	0.30	0.23	0.35	0	0.35	0.26	0.30	0	0.30	0.25	0.20	0.02	0.45	0.27
3	0.50	0	0.50	0.38	0.50	0	0.50	0.37	0.40	0	0.40	0.33	0.35	0.02	0.55	0.34
4	0.75	0	0.75	0.56	0.75	0	0.75	0.55	0.55	0	0.55	0.45	0.55	0.02	0.70	0.43
5	0.95	0	0.95	0.71	1.05	0	1.05	0.77	0.95	0	0.95	0.78	0.75	0.02	1.05	0.64
6	0.70	0	0.70	0.53	0.75	0	0.75	0.55	0.55	0	0.55	0.45	0.50	0.02	0.75	0.46
7	0.90	0	0.90	0.68	1.00	0	1.00	0.74	0.85	0	0.85	0.70	0.70	0.02	0.95	0.58
8	2.05	0	2.15	1.62	2.10	0	2.10	1.54	1.90	0	1.90	1.56	1.70	0.03	2.20	1.34
9	1.40	0	1.40	1.05	1.10	0	1.10	0.81	1.00	0	1.00	0.82	1.10	0.03	1.45	0.88
10	2.05	0	2.05	1.54	2.05	0	2.05	1.51	1.80	0	1.80	1.48	1.90	0.03	2.15	1.31
11	2.20	0	2.20	1.65	2.10	0	2.10	1.54	1.95	0	1.95	1.60	1.85	0.03	2.20	1.34
12	2.25	0	2.25	1.69	2.30	0	2.30	1.69	2.00	0	2.00	1.64	2.20	0.03	2.60	1.58
13	2.55	0	2.55	1.92	2.65	0	2.65	1.95	2.25	0	2.25	1.84	2.50	0.03	2.80	1.71
14	2.00	0	2.00	1.50	2.15	0	2.15	1.58	1.80	0	1.80	1.48	2.20	0	2.40	1.46
15	1.65	0	1.65	1.24	1.80	0	1.80	1.32	1.60	0	1.60	1.31	1.90	0	1.90	1.16
16	1.75	0	1.75	1.32	1.85	0	1.85	1.36	1.65	0	1.65	1.35	2.45	0	2.45	1.49
17	2.20	0	2.20	1.65	2.35	0	2.35	1.73	2.10	0	2.10	1.72	2.60	0	2.60	1.58
18	1.90	0	1.90	1.43	2.10	0	2.10	1.54	1.90	0	1.90	1.56	2.20	0	2.20	1.34
19	1.50	0	1.50	1.13	1.45	0	1.45	1.07	1.30	0	1.30	1.07	1.70	0	1.70	1.04
20					1.00	0	1.00	0.74	1.35	0	1.35	1.11	2.40	0.01	3.15	1.92
21	0.70	0	0.70	0.53	0.90	0	0.90	0.66	0.75	0	0.75	0.62	0.80	0	0.85	0.52
22	0.70	0	0.70	0.53	0.70	0	0.70	0.52	0.60	0	0.60	0.49	0.70	0.02	1.25	0.76
23	0.75	0	0.75	0.56	0.90	0	0.90	0.66	0.95	0	0.95	0.78	0.20	0.02	1.50	0.91
24	0.50	0	0.50	0.38	0.40	0	0.40	0.29	0.40	0	0.40	0.33	0.25	0.02	1.10	0.67
AVERAGE			1.33				1.36				1.22				1.64	
AREA DESIGN FOR FLOORBEAMS 10-19																
STATIC					3.96				3.60				3.96			
DYNAMIC					6.30				5.73				6.30			

NOTES: STRESSES SHOWN ARE TENSION VALUES IN KSI.

"SIMULT"- SIMULTANEOUS STRESSES WITH MAXIMUM STRESS AT FLOORBEAM 17.

"TIME LAG" BETWEEN SIMULTANEOUS AND MAXIMUM STRESS IN SECONDS.

"MAX." ARE MAXIMUM RECORDED STRESSES AT EACH FLOORBEAM.

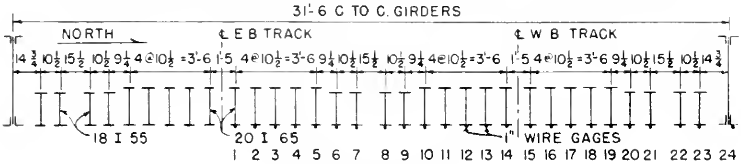
"RATIO" OF RECORDED MAXIMUM STRESS TO AVERAGE RECORDED MAXIMUM STRESS.

FIG 45

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

22'-5 I-BEAM SPAN - BALLASTED CONCRETE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



SECTION PERPENDICULAR TO ℄ OF TRACK

BEFORE REINFORCING																
TEST TRAIN	WESTBOUND												EASTBOUND *			
	3 - AXLE DIESEL								4 - 6 - 2				4 - 6 - 4			
	NYC 4000				NYC 4000				NYC 4856				NYC 5444			
RUN NO.	1				2				12				16			
SPEED IN MPH.	74 6				75.6				19.4				26 EST.			
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST WHEEL AT 119' WEST OF ℄ SPAN				FIRST WHEEL AT 43.1' WEST OF ℄ SPAN				FIRST DRIVER AT 5.8' WEST OF ℄ SPAN				FIRST DRIVER AT			
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOOR-BEAM NO.	SIMULT	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
1	0.20	0.02	0.30	0.17	0.55	0	0.55	0.32	0.35	0.02	0.50	0.31			4.05	2.94
2	0.30	0.02	0.35	0.19	0.55	0	0.55	0.32	0.35	0.02	0.50	0.31			3.15	2.28
3	0.40	0.02	0.50	0.28	0.60	0	0.60	0.35	0.45	0.02	0.60	0.37			3.30	2.40
4	0.70	0.02	0.80	0.44	0.75	0	0.75	0.43	0.70	0	0.70	0.43			2.90	2.10
5	1.20	0.01	1.30	0.72	1.10	0.01	1.25	0.72	1.20	0	1.20	0.74			3.05	2.20
6	0.70	0.01	0.75	0.42	0.80	0.01	0.85	0.49	0.80	0	0.80	0.49			1.25	0.91
7	1.00	0.01	1.20	0.67	0.95	0.01	1.05	0.61	1.10	0	1.10	0.68			1.05	0.76
8	2.60	0.01	2.70	1.50	2.05	0.02	2.35	1.36	2.55	0	2.55	1.56			2.30	1.67
9	1.60	0.01	1.70	0.95	1.25	0.02	1.60	0.92	1.35	0	1.35	0.83			1.05	0.76
10	2.60	0	2.60	1.44	2.20	0.02	2.30	1.33	2.40	0	2.40	1.47			1.10	0.80
11	2.70	0	2.70	1.50	2.25	0.02	2.40	1.39	1.05	0	1.05	0.64			0.65	0.47
12	3.10	0	3.10	1.72	2.50	0.02	2.60	1.50	2.60	0	2.60	1.60			0.45	0.33
13	3.55	0	3.55	1.97	3.20	0.02	3.35	1.94	3.45	0	3.45	2.12			0.50	0.36
14	2.85	0	2.85	1.58	2.65	0	2.65	1.53	2.60	0	2.60	1.60			0.30	0.22
15	1.90	0	1.90	1.06	1.80	0	1.80	1.04	2.25	0	2.25	1.37			0.20	0.14
16	2.50	0	2.50	1.39	2.25	-.30	2.55	1.47	2.45	0	2.45	1.50			0.30	0.22
17	2.85	0	2.85	1.58	2.75	0	2.75	1.59	2.35	0	2.35	1.44			0.20	0.14
18	2.50	0	2.50	1.39	2.25	-.30	2.40	1.39	2.70	0	2.70	1.66			0.20	0.14
19	1.70	0	1.70	0.95	1.65	-.30	1.70	0.98	1.85	0	1.85	1.14			0.15	0.11
20	2.20	0.05	3.00	1.67	2.85	-.30	3.25	1.88	2.05	0	2.05	1.26			0.40	0.29
21	0.80	-.01	1.00	0.56	1.00	0	1.00	0.58	1.05	0	1.05	0.64			0.15	0.11
22	0.80	-.01	1.00	0.56	1.00	0.01	1.05	0.61	0.55	0.01	0.75	0.46			0.20	0.14
23	0.80	0.06	1.25	0.69	0.45	0.01	1.15	0.66	1.30	0.01	1.50	0.92			0.25	0.18
24	0.50	0.04	1.00	0.56	0.35	0.01	0.90	0.52	0.40	0.01	0.65	0.40			0.15	0.11
AVERAGE			1.80				1.73				1.63				1.38	
AREA DESIGN FOR FLOORBEAMS 10 - 19																
STATIC	3.96				3.96				4.44							
DYNAMIC	6.30				6.30				7.95							

NOTE: * EASTBOUND ON EASTBOUND TRACK.

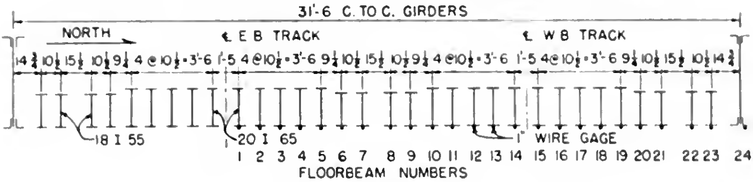
FOR OTHER NOTES SEE FIG 44

FIG. 46

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

22'-1" I-BEAM SPAN - BALLASTED CONCRETE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



SECTION PERPENDICULAR TO ℄ OF TRACK

TEST TRAIN	BEFORE REINFORCING															
	WESTBOUND															
	LOCOMOTIVE TYPE: 4-6-4												2-8-4			
	NYC 5321				NYC 5261				NYC 5454				PM 1227			
RUN NO.	10				4				11				8			
SPEED IN MPH.	43.9				46.0				74.6				15.7			
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST DRIVER AT															
	6.4' WEST OF ℄ SPAN				6.1' WEST OF ℄ SPAN				4.2' WEST OF ℄ SPAN				23.2' WEST OF ℄ SPAN			
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOOR-BEAM NO.	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
1	0.35	0.02	0.55	0.26	0.60	0.02	0.70	0.33	0.30	0.07	0.80	0.36	0.85	0	0.85	0.34
2	0.35	0.02	0.45	0.21	0.40	0.02	0.65	0.30	0.20	0.07	0.65	0.29	0.75	0	0.75	0.30
3	0.50	0.02	0.65	0.31	0.70	0.02	0.90	0.42	0.50	0.07	1.05	0.47	0.85	0	0.85	0.34
4	0.80	0.01	0.85	0.40	0.95	0.02	1.15	0.55	0.75	0.07	1.15	0.51	1.10	0	1.10	0.44
5	1.40	0	1.40	0.67	1.65	0.02	1.70	0.79	1.55	0.07	1.65	0.74	1.60	0	1.60	0.64
6	0.90	0	0.90	0.43	1.00	0.01	1.10	0.51	0.85	0.01	1.10	0.49	1.10	0	1.10	0.44
7	1.25	0	1.25	0.60	1.40	0.01	1.50	0.70	1.20	0.01	1.35	0.60	1.50	0	1.50	0.60
8	2.90	0	2.90	1.38	3.10	0.01	3.40	1.59	3.40	0	3.40	1.52	3.35	0	3.35	1.34
9	1.85	0	1.85	0.88	2.00	0.01	2.10	0.98	1.85	0	1.85	0.83	1.85	0	1.85	0.74
10	2.85	0	2.85	1.36	0.70	0.02	0.75	0.35	2.95	0	2.95	1.32	3.30	0	3.30	1.32
11	3.00	0	3.00	1.43	0.70	0.01	0.90	0.42	3.20	0	3.20	1.43	3.55	0	3.55	1.42
12	3.15	0	3.15	1.50	3.40	0.01	3.50	1.64	3.20	0	3.20	1.43	4.00	0	4.00	1.60
13	4.35	0	4.35	2.07	3.90	0.02	4.30	2.00	4.45	0	4.45	1.99	5.10	0	5.10	2.04
14	3.10	0	3.10	1.48	3.30	0	3.30	1.54	3.20	0	3.20	1.43	3.80	0	3.80	1.52
15	2.50	0	2.50	1.19	2.40	0	2.40	1.12	2.60	0	2.60	1.16	3.00	0	3.00	1.20
16	2.85	0	2.85	1.36	3.20	0	3.20	1.50	3.10	0	3.10	1.38	3.70	0	3.70	1.48
17	3.35	0	3.35	1.60	3.65	0	3.65	1.71	3.15	0	3.15	1.41	3.45	0	3.45	1.38
18	3.40	0	3.40	1.62	3.25	0	3.25	1.52	3.25	0	3.25	1.45	3.85	0	3.85	1.54
19	2.25	0	2.25	1.07	2.40	0	2.40	1.12	2.25	0	2.25	1.45	2.60	0	2.60	1.04
20	3.15	0	3.15	1.50	3.50	0.01	4.20	1.96	3.00	0.03	3.70	1.65	2.65	0	2.65	1.06
21	1.45	0	1.45	0.69	1.30	0.01	1.45	0.68	0.90	0.03	1.45	0.65	2.00	0	2.00	0.80
22	0.70	0.01	1.10	0.52	1.20	0.01	1.60	0.75	0.55	0.03	1.35	0.60	1.80	0	1.80	0.72
23	1.10	0.01	2.00	0.95	0.80	0.01	1.80	0.84	0.60	0.03	2.10	0.94	2.60	0	2.60	1.04
24	0.30	0.01	1.10	0.52	0.70	0.01	1.35	0.63	0.05	0.03	0.90	0.40	1.55	0	1.55	0.62
AVERAGE			2.10				2.14				2.24				2.50	
	AREA DESIGN FOR FLOORBEAMS 10 - 19															
STATIC	4.79				4.79				4.79							
DYNAMIC	8.59				8.59				8.59							

FOR NOTES SEE FIG 44

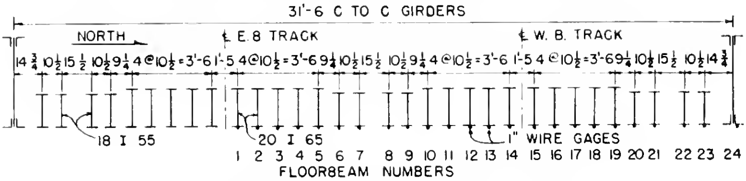
FIG. 47

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

22'-5 I-BEAM SPAN - BALLASTED CONCRETE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS

31'-6 C TO C GIRDERS



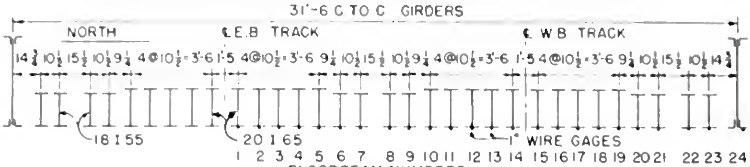
SECTION PERPENDICULAR TO ℄ OF TRACK

BEFORE REINFORCING																
	WESTBOUND															
TEST TRAIN	2-8-4				LOCOMOTIVE TYPE: 4-8-2								4-8-4			
	C&O 2689				NYC 2858				NYC 3015				NYC 6021			
RUN NO.	14				6				15				13			
SPEED IN MPH.	53.4				6.2				40.7				51.9			
LOCOMOT. POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT 9.7' WEST OF ℄ SPAN				4.7' WEST OF ℄ SPAN				5.9' WEST OF ℄ SPAN				4.8' WEST OF ℄ SPAN			
COL. NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOOR-BEAM NO.	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
1	0.60	0.07	0.95	0.32	0.55	0	0.55	0.24	0.30	0.03	0.75	0.31	0.45	0.02	0.70	0.36
2	0.55	0.07	0.85	0.28	0.55	0	0.55	0.24	0.30	0.02	0.70	0.29	0.40	0.02	0.65	0.33
3	0.75	0.07	1.00	0.33	0.80	0	0.80	0.35	0.35	0.02	0.80	0.33	0.65	0.02	0.85	0.43
4	1.05	0.01	1.25	0.42	1.15	0	1.15	0.50	0.65	0.02	1.10	0.45	0.90	0.02	1.00	0.51
5	1.95	0	1.95	0.65	1.65	0	1.65	0.72	1.25	0.02	1.75	0.72	1.65	0	1.65	0.84
6	1.30	0	1.30	0.43	1.00	0	1.00	0.44	0.85	0.02	1.15	0.47	1.00	0	1.00	0.51
7	1.80	0	1.80	0.60	1.55	0	1.55	0.67	1.20	0.07	1.55	0.64	1.45	0	1.45	0.74
8	2.30	0	2.30	0.76	3.45	0	3.45	1.50	3.25	0.07	3.60	1.48	3.15	0	3.15	1.60
9	2.25	0	2.25	0.75	2.30	0	2.30	1.00	1.65	0.07	1.90	0.78	1.65	0	1.65	0.84
10	3.95	0	3.95	1.31	3.20	0	3.20	1.39	3.05	0.07	3.25	1.34	3.00	0	3.00	1.52
11	4.15	0	4.15	1.38	3.50	0	3.50	1.52	3.30	0	3.30	1.36	3.10	0	3.10	1.57
12	4.50	0	4.50	1.50	3.70	0	3.70	1.61	3.65	0	3.65	1.50	3.15	0	3.15	1.60
13	5.85	0	5.85	1.94	4.55	0	4.55	1.98	4.75	0	4.75	1.96	4.25	0	4.25	2.16
14	3.05	0	3.05	1.01	3.60	0	3.60	1.56	2.55	0	2.55	1.05	1.60	0	1.60	0.81
15	3.80	0	3.80	1.26	2.90	0.26	3.00	1.30	3.00	0	3.00	1.24	2.35	0	2.35	1.19
16	4.75	0	4.75	1.58	2.85	0.26	3.05	1.33	3.50	0	3.50	1.44	2.75	0	2.75	1.40
17	4.35	0	4.35	1.45	3.50	0.26	3.80	1.65	3.70	0	3.70	1.52	2.90	0	2.90	1.47
18	4.75	0	4.75	1.58	3.20	0.26	3.45	1.50	3.60	0	3.60	1.48	2.60	0	2.60	1.32
19	3.60	0	3.60	1.20	2.15	0.26	2.40	1.04	2.75	0	2.75	1.13	2.05	0	2.05	1.04
20	5.40	0	5.40	1.80	2.50	0.26	2.95	1.28	3.70	0	3.70	1.52	2.50	0.08	2.90	1.47
21	2.40	0	2.40	0.80	1.20	0.26	1.45	0.63	1.90	0	1.90	0.78	1.25	0	1.25	0.63
22	2.00	0	2.00	0.66	1.10	0.26	1.25	0.54	1.25	0.01	1.60	0.66	0.70	0.08	1.00	0.51
23	2.50	0.01	2.95	0.98	1.35	0.26	1.60	0.70	1.55	0.02	2.40	0.99	0.80	0.08	1.45	0.73
24	3.00	0.01	3.10	1.03	0.60	0.26	0.70	0.30	0.40	0.02	1.25	0.51	0.25	0.08	0.90	0.46
AVERAGE			3.01				2.30				2.43				1.97	
AREA DESIGN FOR FLOORBEAMS 10 - 19																
STATIC					5.02				5.23				5.25			
DYNAMIC					9.00				9.38				9.41			

FOR NOTES SEE FIG. 44

FIG 48
NEW YORK CENTRAL RAILROAD BRIDGE TESTS
22'-5 I-BEAM SPAN - BALLASTED CONCRETE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



SECTION PERPENDICULAR TO ℄ OF TRACK

TEST TRAIN	AFTER REINFORCING															
	WESTBOUND															
	LOCOMOTIVE TYPE : 3 AXLE DIESEL															
	NYC 4209				NYC 4032				NYC 4000				NYC 4034			
RUN NO.	2-12				2-3				2-7				2-16			
SPEED IN MPH	7.6				10.5				15.4				36.2			
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST WHEEL AT															
	9.6' WEST OF ℄ SPAN				7.6' WEST OF ℄ SPAN				8.0' WEST OF ℄ SPAN				13.6' WEST OF ℄ SPAN			
COL NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOOR-BEAM NO.	SIMULT	TIME LAG	MAX	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
1	0.25	0	0.25	0.43	0.25	0	0.25	0.39	0.25	0	0.25	0.35	0.10	-0.04	0.20	0.29
2	0.40	0	0.40	0.69	0.40	0	0.40	0.63	0.30	0	0.30	0.46	0.20	-0.04	0.30	0.44
3	0.35	0	0.35	0.60	0.30	0	0.30	0.47	0.30	0	0.30	0.46	0.25	-0.04	0.35	0.51
4	0.35	0	0.35	0.60	0.35	0	0.35	0.55	0.35	0	0.35	0.54	0.25	-0.04	0.35	0.51
5	0.50	0	0.50	0.86	0.45	0	0.45	0.70	0.40	0	0.40	0.62	0.35	-0.04	0.45	0.65
6	0.45	0	0.45	0.78	0.40	0	0.40	0.63	0.45	0	0.45	0.69	0.25	-0.04	0.40	0.58
7	0.45	0	0.45	0.78	0.60	0	0.60	0.94	0.35	0	0.35	0.54	0.35	-0.04	0.45	0.65
8	0.55	0	0.55	0.95	0.70	0	0.70	1.09	0.55	0	0.55	0.85	0.50	-0.04	0.65	0.94
9	0.65	0	0.65	1.12	0.70	0	0.70	1.09	0.65	0	0.65	1.00	0.60	-0.04	0.75	1.09
10	0.70	0	0.70	1.21	0.85	0	0.85	1.33	0.75	0	0.75	1.15	0.65	-0.04	0.80	1.16
11	0.85	0	0.85	1.46	0.90	0	0.90	1.41	0.90	0	0.90	1.38	0.75	-0.04	0.90	1.30
12	0.75	0	0.75	1.29	0.85	0	0.85	1.33	0.90	0	0.90	1.38	0.75	-0.04	1.00	1.45
13	0.70	0	0.70	1.21	0.80	0	0.80	1.25	0.80	0	0.80	1.23	0.80	-0.04	0.90	1.30
14	0.65	0	0.65	1.12	0.65	0	0.65	1.00	0.65	0	0.65	1.00	0.75	-0.10	0.80	1.16
15	0.60	0	0.60	1.03	0.70	0	0.70	1.09	0.70	0	0.70	1.08	0.75	0	0.75	1.09
16	0.85	0	0.85	1.46	0.75	0	0.75	1.17	0.95	0	0.95	1.46	1.00	0	1.00	1.45
17	0.75	0	0.75	1.29	0.90	0	0.90	1.41	0.85	0	0.85	1.31	1.00	0	1.00	1.45
18	0.70	0	0.70	1.21	0.85	0	0.85	1.33	1.00	0	1.00	1.54	0.90	0	0.90	1.30
19	0.65	0	0.65	1.12	0.70	0	0.70	1.09	0.70	0	0.70	1.08	0.80	0	0.80	1.16
20	0.65	0	0.65	1.12	0.65	0	0.65	1.00	0.90	0	0.90	1.38	0.85	0	0.85	1.23
21	0.60	0	0.60	1.03	0.65	0	0.65	1.00	0.70	0	0.70	1.08	0.65	0	0.65	0.94
22	0.50	0	0.50	0.86	0.55	0	0.55	0.86	0.70	0	0.70	1.08	0.65	0	0.65	0.94
23	0.50	0	0.50	0.86	0.65	0	0.65	1.00	0.75	0	0.75	1.15	0.50	0.01	0.80	1.16
24	0.60	0	0.60	1.03	0.70	0	0.70	1.09	0.75	0	0.75	1.15	0.60	0.01	0.80	1.16
AVERAGE			0.58				0.64				0.65				0.69	
	AREA DESIGN FOR FLOORBEAMS 10-19															
STATIC	3.60				3.96				3.96				3.96			
DYNAMIC	5.73				6.30				6.30				6.30			

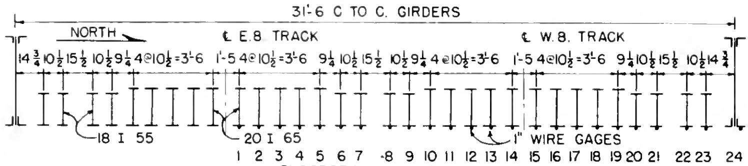
FOR NOTES SEE FIG 44

FIG. 49

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

22'-5 I - BEAM SPAN - BALLASTED CONCRETE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



SECTION PERPENDICULAR TO ℄ OF TRACK

	AFTER REINFORCING															
TEST TRAIN	WESTBOUND LOCOMOTIVE TYPE: 3 AXLE DIESELS															
	NYC 4103				NYC 4200				NYC 4033				C.& O. 103			
RUN NO.	2-10				2-14				2-17				2-9			
SPEED IN MPH.	44.5				52.4				61.4				75.4			
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST WHEEL AT 11.1' WEST OF ℄ SPAN				71.6' WEST OF ℄ SPAN				51.1' WEST OF ℄ SPAN				7.6' WEST OF ℄ SPAN			
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOOR BEAM NO.	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
1	0.30	0	0.30	0.42	0.25	0	0.25	0.42	0.25	0	0.25	0.40	0.25	0	0.25	0.34
2	0.45	0	0.45	0.63	0.25	0	0.25	0.42	0.35	0	0.35	0.56	0.30	0	0.30	0.41
3	0.40	0	0.40	0.56	0.25	0	0.25	0.42	0.30	0	0.30	0.48	0.35	0	0.35	0.47
4	0.45	0	0.45	0.63	0.25	-0.75	0.30	0.50	0.40	0	0.40	0.65	0.45	0	0.45	0.61
5	0.80	0	0.80	1.11	0.25	-0.75	0.40	0.67					0.45	0	0.45	0.61
6	0.45	0	0.45	0.63	0.30	-0.75	0.35	0.58	0.40	0	0.40	0.65	0.50	0	0.50	0.68
7	0.55	0	0.55	0.76	0.25	-0.75	0.40	0.67	0.45	0	0.45	0.73	0.50	0	0.50	0.68
8	0.65	0	0.65	0.90	0.45	-0.75	0.55	0.92	0.55	0	0.55	0.89	0.70	0	0.70	0.95
9	0.70	0	0.70	0.97	0.50	0	0.50	0.83	0.65	0	0.65	1.05	0.75	0	0.75	1.00
10	0.75	0	0.75	1.04	0.60	0	0.60	1.00	0.70	0	0.70	1.13	0.85	0	0.85	1.15
11	0.85	0	0.85	1.18	0.65	-0.75	0.75	1.25	0.75	0	0.75	1.21	1.05	0	1.05	1.42
12	0.85	0	0.85	1.18	0.65	-0.75	0.75	1.25	0.75	0	0.75	1.21	0.95	0	0.95	1.28
13	0.90	0	0.90	1.25	0.80	0	0.80	1.33	0.80	0	0.80	1.29	0.90	0	0.90	1.22
14	0.80	0	0.80	1.11	0.90	0	0.90	1.50	0.75	0	0.75	1.21	0.85	0	0.85	1.15
15	0.85	0	0.85	1.18	0.90	0	0.90	1.50	0.80	0	0.80	1.29	0.95	0	0.95	1.28
16	0.95	0	0.95	1.32	0.80	0	0.80	1.33	0.95	0	0.95	1.53	1.10	0	1.10	1.49
17	1.00	0	1.00	1.39	0.90	0	0.90	1.50	0.95	0	0.95	1.53	1.15	0	1.15	1.56
18	0.90	0	0.90	1.25	0.95	0	0.95	1.58	0.85	0	0.85	1.37	1.00	0	1.00	1.35
19	0.85	0	0.85	1.18	0.75	0	0.75	1.25	0.70	0	0.70	1.13	0.85	0	0.85	1.15
20	0.80	0	0.80	1.11	0.65	0	0.65	1.08	0.70	0	0.70	1.13	0.80	0	0.80	1.08
21	0.75	0	0.75	1.04	0.65	0	0.65	1.08	0.60	0	0.60	0.97	0.75	0	0.75	1.00
22	0.70	0	0.70	0.97	0.65	0	0.65	1.08	0.45	0	0.45	0.73	0.65	0	0.65	0.88
23	0.70	0.02	0.80	1.11	0.70	0	0.70	1.17	0.50	0	0.50	0.81	0.70	0	0.70	0.95
24	0.55	0.01	0.65	0.90	0.60	0	0.60	1.00	0.60	0	0.60	0.97	0.85	0	0.85	1.00
AVERAGE			0.72				0.61				0.62				0.74	
	AREA DESIGN FOR FLOORBEAMS 10 - 19															
STATIC	3.82				3.60				3.96							
DYNAMIC	6.08				5.73				6.30							

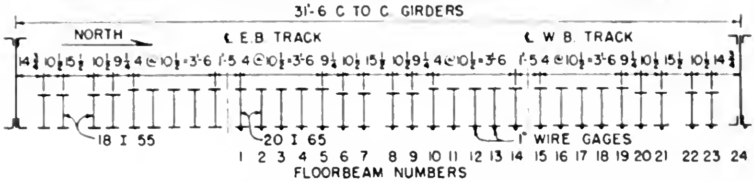
FOR NOTES SEE FIG 44

FIG. 50

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

22'-5 I-BEAM SPAN - BALLASTED CONCRETE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



SECTION PERPENDICULAR TO ℄ OF TRACK

	AFTER REINFORCING															
TEST TRAIN	WESTBOUND															
	LOCO. TYPE: 3 AXLE DIESEL								LOCOMOTIVE TYPE: 4-6-4							
	NYC 4016				NYC 4021				NYC 5267				NYC 5296			
RUN NO.	2-6				2-15				2-18				2-13			
SPEED IN MPH.	76.5				78.4				3.6				42.6			
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST WHEEL AT								FIRST DRIVER AT							
	5.4' WEST OF ℄ SPAN				57.4' WEST OF ℄ SPAN				2.2' WEST OF ℄ SPAN				7.5' WEST OF ℄ SPAN			
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOOR-BEAM NO.	SIMULT.	TIME LAG	MAX	RATIO	SIMULT.	TIME LAG	MAX	RATIO	SIMULT.	TIME LAG	MAX	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
1	0.20	0.02	0.30	0.40	0.15	-0.08	0.30	0.38	0.40	0	0.40	0.44	0.20	0.02	0.30	0.32
2	0.20	0.02	0.35	0.47	0.20	-0.04	0.35	0.44	0.45	0	0.45	0.49	0.30	0.01	0.45	0.48
3	0.20	0.01	0.30	0.40	0.25	0.12	0.40	0.50	0.45	0	0.45	0.49	0.35	0.01	0.40	0.43
4	0.30	0.01	0.40	0.53	0.20	0.12	0.45	0.57	0.55	0	0.55	0.60	0.40	0.01	0.45	0.48
5	0.30	0.02	0.40	0.53	0.35	0.12	0.50	0.63	0.60	0	0.60	0.66	0.45	0.01	0.60	0.64
6	0.30	0.03	0.45	0.60	0.30	0.12	0.50	0.63	0.60	0	0.60	0.66	0.40	0.01	0.55	0.59
7	0.40	0.02	0.50	0.67	0.30	0.12	0.55	0.69	0.60	0	0.60	0.66	0.45	0.01	0.55	0.59
8	0.60	0.02	0.70	0.93	0.45	0.12	0.65	0.82	0.85	0	0.85	0.93	0.65	0.01	0.75	0.80
9	0.70	0.02	0.80	1.07	0.55	0.12	0.80	1.00	0.90	0	0.90	0.99	0.65	0.01	0.80	0.86
10	0.80	0.02	0.90	1.20	0.60	0.12	0.85	1.04	1.05	0	1.05	1.16	0.85	0.01	1.05	1.12
11	0.95	0.02	1.10	1.47	0.80	0.12	1.00	1.26	1.20	0	1.20	1.32	1.05	0.01	1.30	1.39
12	1.00	0.02	1.05	1.40	0.70	0.12	0.90	1.14	1.25	0	1.25	1.37	0.95	0.01	1.15	1.24
13	0.80	0.02	1.00	1.33	1.05	0	1.05	1.32	1.15	0	1.15	1.26	1.05	-0.06	1.25	1.34
14	0.70	0.02	0.80	1.07	1.05	0	1.05	1.32	1.05	0	1.05	1.16	1.05	0.02	1.20	1.29
15	1.00	0	1.00	1.33	1.05	0	1.05	1.32	1.20	0	1.20	1.32	1.15	0	1.15	1.24
16	1.05	0	1.05	1.40	1.05	0	1.05	1.32	1.25	0	1.25	1.37	1.35	0	1.35	1.45
17	1.05	0	1.05	1.40	1.15	0	1.15	1.45	1.25	0	1.25	1.37	1.35	0	1.35	1.45
18	1.05	0	1.05	1.40	1.15	0	1.15	1.45	1.25	0	1.25	1.37	1.30	0	1.30	1.39
19	0.75	0.01	0.85	1.13	1.05	0	1.05	1.32	1.10	0	1.10	1.21	1.05	0.01	1.15	1.24
20	0.65	0.01	0.75	1.00	1.00	0	1.00	1.26	0.95	0	0.95	1.04	1.05	0.01	1.15	1.24
21	0.70	0	0.70	0.93	0.85	0	0.85	1.04	0.95	0	0.95	1.04	0.90	0.01	1.00	1.07
22	0.50	0.01	0.75	1.00	0.65	0	0.65	0.82	0.75	0	0.75	0.82	0.75	0.01	0.90	0.97
23	0.50	0.01	0.80	1.07	0.80	0	0.80	1.00	0.90	0	0.90	0.99	0.75	0.01	1.05	1.12
24	0.60	0.01	0.90	1.20	0.90	0	0.90	1.14	1.05	0	1.05	1.16	0.80	0.01	1.20	1.29
AVERAGE			0.75				0.79				0.91				0.93	
	AREA DESIGN FOR FLOORBEAMS 10-19															
STATIC	3.96				3.96				4.99				4.79			
DYNAMIC	6.30				6.30				8.95				8.59			

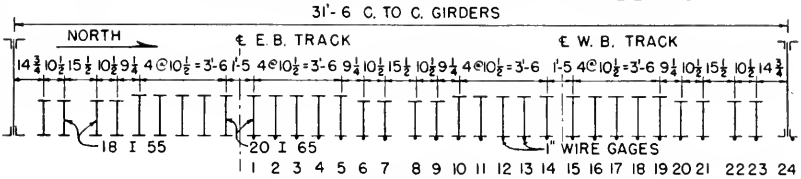
FOR NOTES SEE FIG 44

FIG. 51

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

22'-5 I BEAM SPAN - BALLASTED CONCRETE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



FLOORBEAM NUMBERS

SECTION PERPENDICULAR TO ℄ OF TRACK

AFTER REINFORCING												
TEST TRAIN	WESTBOUND											
	LOCOMOTIVE TYPE: 4-6-4								2-8-4			
	NYC 5318				NYC 5295				PM 1217			
RUN NO.	2-4				2-11				2-2			
SPEED IN MPH	51.8				53.7				54.1			
LOCOMOT. POSITION FOR SIMULTAN. STRESS	FIRST DRIVER AT											
	8.6' WEST OF ℄ SPAN				8.2' WEST OF ℄ SPAN				12.2' WEST OF ℄ SPAN			
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13
FLOOR-BEAM NO.	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
1	0.25	0.02	0.40	0.38	0.35	0.01	0.45	0.42	0.40	0.06	0.50	0.39
2	0.30	0.02	0.50	0.47	0.45	0.01	0.55	0.51	0.40	0.06	0.55	0.43
3	0.35	0.02	0.50	0.47	0.45	0.01	0.60	0.56	0.50	0.06	0.65	0.50
4	0.40	0.01	0.60	0.57	0.70	0	0.70	0.66	0.65	0.06	0.80	0.62
5	0.50	0.02	0.70	0.66	0.80	0	0.80	0.75	0.45	0.02	0.65	0.50
6	0.55	0.02	0.70	0.66	0.70	0	0.70	0.66	0.70	0.06	0.85	0.66
7	0.50	0.02	0.70	0.66	0.75	0	0.75	0.70	0.65	0.02	0.85	0.66
8	0.80	-.04	1.00	0.94	1.00	0	1.00	0.94	1.00	0.02	1.15	0.90
9	0.90	-.04	1.15	1.09	1.10	0	1.10	1.03	1.20	0.01	1.40	1.19
10	1.00	-.03	1.30	1.23	1.35	0	1.35	1.26	1.35	0.01	1.60	1.24
11	1.20	-.04	1.45	1.37	1.55	0	1.55	1.45	1.55	0.01	1.65	1.28
12	1.25	0.01	1.45	1.37	1.45	0	1.45	1.36	1.70	0.01	1.90	1.47
13	1.35	0	1.35	1.27	1.30	0	1.30	1.22	1.40	0.01	1.65	1.28
14	1.20	0	1.20	1.13	1.05	0.01	1.15	1.08	1.20	0.01	1.60	1.24
15	1.55	0	1.55	1.46	1.25	0	1.25	1.17	1.40	0.01	1.80	1.40
16	1.55	0	1.55	1.46	1.50	0	1.50	1.40	1.45	0.01	1.90	1.47
17	1.55	0	1.55	1.46	1.40	0	1.40	1.31	1.80	0	1.80	1.40
18	1.60	0	1.60	1.51	1.40	0	1.40	1.31	1.60	0	1.60	1.24
19	1.35	0	1.35	1.27	1.30	0	1.30	1.22	1.20	0.01	1.40	1.09
20	1.25	0	1.25	1.18	1.20	0	1.20	1.12	1.20	0.01	1.50	1.16
21	1.10	0	1.10	1.04	0.95	0	0.95	0.89	1.00	0.01	1.25	0.97
22	1.10	0	1.10	1.04	0.95	0	0.95	0.89	0.95	0.01	1.20	0.93
23	1.15	0	1.15	1.09	1.00	0	1.00	0.94	1.10	0.01	1.25	0.97
24	1.30	0	1.30	1.23	1.30	0	1.30	1.22	1.20	0.01	1.50	1.16
AVERAGE			1.06				1.07				1.29	
AREA DESIGN FOR FLOORBEAMS 10-19												
STATIC	4.79				4.79							
DYNAMIC	8.59				8.59							

FOR NOTES SEE FIG 44

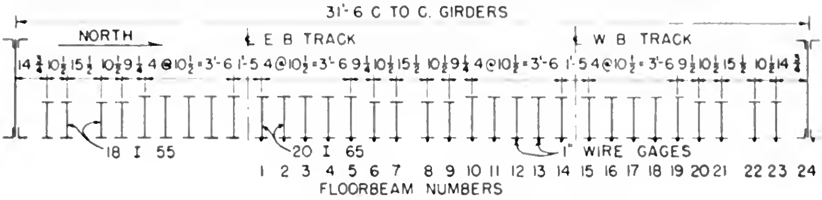
FIG 52

NEW YORK CENTRAL RAILROAD BRIDGE TESTS

22'-5 I - BEAM SPAN - BALLASTED CONCRETE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS

31'-6 C TO C. GIRDERS



SECTION PERPENDICULAR TO ℄ OF TRACK

AFTER REINFORCING												
TEST TRAIN	EASTBOUND *											
	LOCOMOTIVE TYPE: 4 - 6 - 4											
	NYC 5295				NYC 5317				NYC 5246			
RUN NO.	2 - 5				2 - 1				2 - 8			
SPEED IN MPH	5 EST.				30 EST.				30 EST			
LOCOMOT. POSITION FOR SIMULTAN STRESS	FIRST DRIVER AT											
	NO LOCOMOTIVE POSITION DETERMINED											
COL. NO. 1	2	3	4	5	6	7	8	9	10	11	12	13
FLOOR-BEAM NO.	SIMULT	TIME LAG	MAX	RATIO	SIMULT	TIME LAG	MAX	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
1			1.25	2.55			1.40	2 12			1.20	2.26
2			1.30	2.65			1.45	2.20			1.30	2.46
3			1.05	2.15			1 25	1.90			1.20	2.26
4			1.00	2.04			1 20	1.82			1.05	1.98
5			0.90	1.84			1.10	1.67			1.10	2.08
6			0.90	1.84			1.15	1.74			1.00	1.89
7			0.90	1.84			1.05	1.60			0.95	1.79
8			0.60	1.22			0.70	1.06			0.65	1.23
9			0.50	1.02			0.65	0.98			0.50	0.95
10			0.45	0.92			0.55	0.83			0.50	0.95
11			0.40	0.81			0 55	0.83			0.45	0.85
12			0.40	0.81			0.45	0.68			0.40	0.76
13			0.35	0.71			0.40	0.61			0.40	0.76
14			0.25	0.51			0.50	0.76			0.30	0.57
15			0.20	0.41			0.45	0.68			0.20	0.38
16			0.20	0.41			0.35	0.53			0.25	0.47
17			0.20	0.41			0.40	0.61			0.30	0.57
18			0.20	0.41			0.40	0.61			0.25	0.47
19			0.20	0.41			0.30	0.45			0.20	0.38
20			0.10	0.20			0.30	0.45			0.15	0.28
21			0.20	0.41			0.25	0.38			0.10	0.19
22			0.15	0.31			0.40	0.61			0.10	0.19
23			0	0			0.35	0.53			0.10	0.19
24			0	0			0 35	0.53			0.10	0.19
AVERAGE			0.49				0.66				0.53	

NOTE * EASTBOUND ON EASTBOUND TRACK.

FOR OTHER NOTES SEE FIG 44

FOR COMPARISON SEE FIG 45

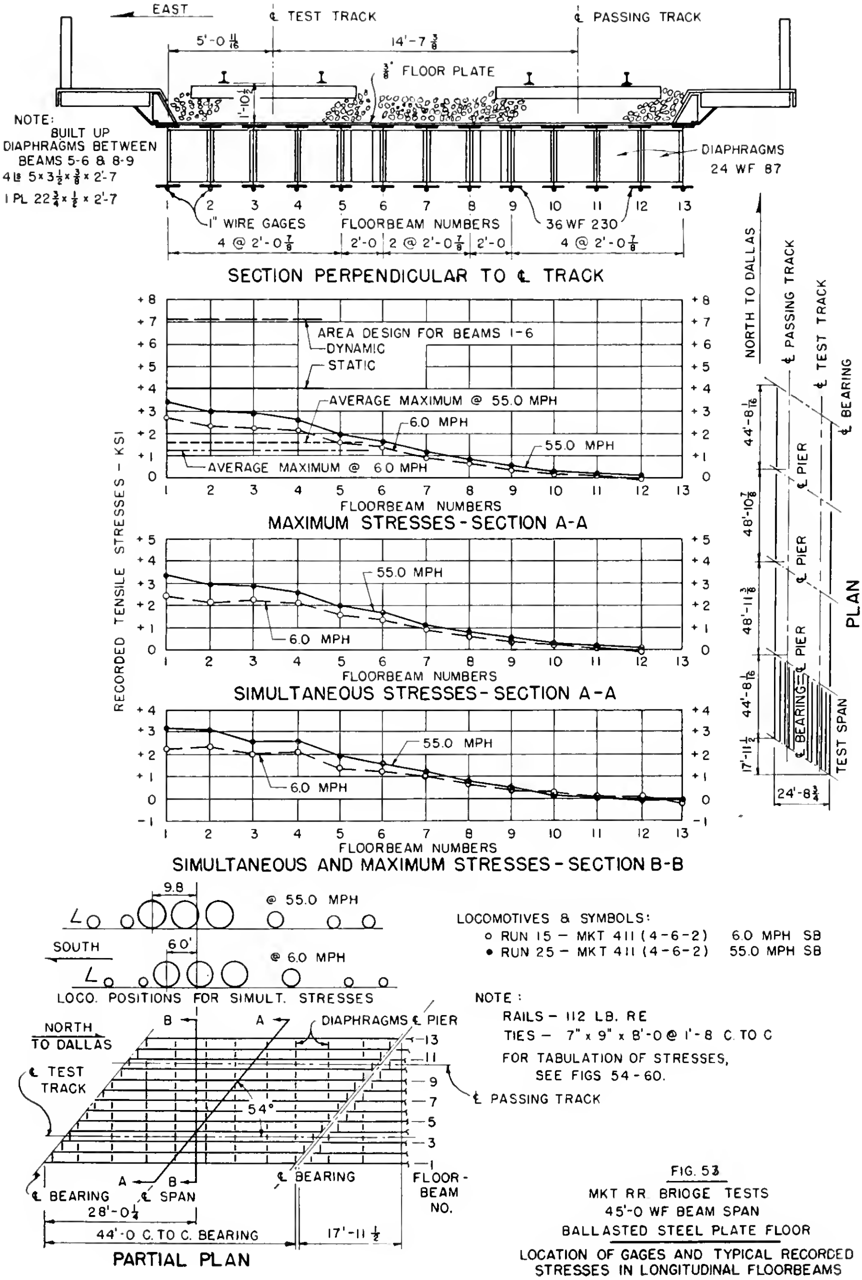


FIG. 53

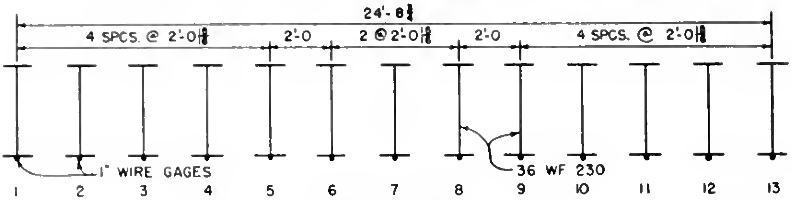
MKT RR BRIDGE TESTS
45'-0 WF BEAM SPAN
BALLASTED STEEL PLATE FLOOR

LOCATION OF GAGES AND TYPICAL RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS

FIG. 54

MISSOURI - KANSAS - TEXAS RAILROAD BRIDGE TESTS
45'-0 WIDE FLANGE BEAM SPAN-BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



FLOORBEAM NUMBERS

SECTION PERPENDICULAR TO ℄ OF TRACK

TEST TRAIN		SOUTHBOUND												NORTHBOUND			
		LOCOMOTIVE TYPE: 2 AXLE DIESEL															
		C.B.&Q. 106				MKT 331				MKT 332				R I 146			
RUN NO.		32				30				9				31			
SPEED IN MPH.		4.5				10.4				41.2				7.3			
LOCOMOT. POSITION FOR SIMULTAN. STRESS		FIRST WHEEL AT															
		138' SOUTH OF INTERSECTION				52.5' SOUTH OF INTERSECTION				38.3' SOUTH OF INTERSECTION				6.8' NORTH OF INTERSECTION			
COL. NO. 1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOOR-BEAM NO.		SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
SECTION A-A	1	2.40	0	2.40	1.97	1.80	-0.23	1.85	1.99	1.95	0.18	2.20	2.24	1.65	3.70	1.85	2.06
	2	2.10	0	2.10	1.72	1.60	0.17	1.65	1.77	1.50	0.32	1.60	1.63	1.60	3.70	1.65	1.83
	3	2.10	0	2.10	1.72	1.80	0	1.80	1.94	1.85	0	1.85	1.89	1.65	0	1.65	1.83
	4	2.00	0	2.00	1.64	1.50	0	1.50	1.61	1.65	0	1.65	1.68	1.50	0	1.50	1.67
	5	1.65	0	1.65	1.35	1.20	0	1.20	1.29	1.25	0.78	1.40	1.43	1.10	0	1.10	1.22
	6	1.35	0	1.35	1.11	1.05	-0.18	1.10	1.18	1.05	0.18	1.15	1.17	1.00	2.87	1.05	1.17
	7	1.00	-0.24	1.05	0.86	0.75	-0.34	0.80	0.86	0.75	0.10	0.85	0.87	0.65	0.58	0.75	0.83
	8	0.75	-0.24	0.80	0.66	0.50	1.69	0.55	0.59	0.55	0.10	0.60	0.61	0.45	0.64	0.55	0.61
	9	0.55	0	0.55	0.45	0.30	1.69	0.35	0.38	0.25	0.34	0.30	0.31	0.30	0.64	0.40	0.44
	10	0.35	0	0.35	0.29	0.20	0	0.20	0.22	0.15	0.10	0.20	0.20	0.20	0.64	0.25	0.28
	11	0.25	0	0.25	0.20	0.05	1.69	0.10	0.11	0.05	0.10	0.10	0.10	0.05	0	0.05	0.06
	12	0.05	0	0.05	0.04	0.05	0	0.05	0.05	-0.05	0.10	-0.10		0	0	0	0
	AVE.			1.22				0.93				0.98				0.90	
SECTION B-B	1	1.80	0	1.80	2.00	1.50	0	1.50	2.01	1.55	0	1.55	2.12	1.45	0	1.45	2.16
	2	2.00	0	2.00	2.22	1.60	0	1.60	2.16	1.60	0	1.60	2.19	1.50	0	1.50	2.24
	3	1.60	0	1.60	1.78	1.35	0	1.35	1.82	1.35	0	1.35	1.85	1.30	0	1.30	1.94
	4	2.00	0	2.00	2.22	1.50	0	1.50	2.01	1.65	0	1.65	2.26	1.50	0	1.50	2.24
	5	1.40	0	1.40	1.56	1.10	0	1.10	1.48	1.30	0	1.30	1.78	1.05	0	1.05	1.57
	6	1.10	0	1.10	1.22	0.90	0	0.90	1.22	1.00	0	1.00	1.37	0.80	0	0.80	1.19
	7	0.85	0	0.85	0.95	0.70	0	0.70	0.95	0.65	0	0.65	0.89	0.60	0	0.60	0.90
	8	0.60	0	0.60	0.67	0.50	0	0.50	0.68	0.45	0	0.45	0.62	0.35	0	0.35	0.52
	9	0.30	0	0.30	0.33	0.30	0	0.30	0.41	0.20	0	0.20	0.27	0.20	0	0.20	0.30
	10	0.20	0	0.20	0.22	0.20	0	0.20	0.27	0	0	0	0	0.10	0	0.10	0.15
	11	0	0	0	0	0.05	0	0.05	0.07	-0.05	0	-0.05		0	0	0	0
	12	-0.05	0	-0.05		-0.05	0	-0.05		-0.05	0	-0.05		-0.05	0	-0.05	
	13	-0.15	0	-0.15		-0.05	0	-0.05		-0.10	0	-0.10		-0.10	0	-0.10	
	AVE.			0.90				0.74								0.67	
AREA DESIGN FOR FLOORBEAMS 1-6 AT SECTION A-A																	
STATIC		3.42				2.87				2.87				2.71			
DYNAMIC		5.35				4.49				4.49				4.24			

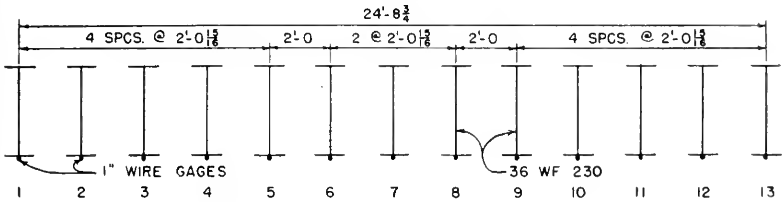
NOTES: STRESSES SHOWN ARE TENSION VALUES IN KSI.
"SIMULT."- SIMULTANEOUS STRESSES WITH MAXIMUM STRESS AT FLOORBEAM 4
"TIME LAG" IN SECONDS
"MAX." ARE MAXIMUM RECORDED STRESSES AT EACH FLOORBEAM
"RATIO" OF RECORDED MAXIMUM STRESS TO AVERAGE RECORDED MAXIMUM STRESS
* INTERSECTION OF ℄ TRACK AND ℄ SPAN.

FIG. 55

MISSOURI-KANSAS-TEXAS RAILROAD BRIDGE TESTS

45'-0 WIDE FLANGE BEAM SPAN-BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



SECTION PERPENDICULAR TO ℄ OF TRACK

TEST TRAIN		NORTHBOUND												SOUTHBOUND			
		LOCOMOTIVE TYPE: 2 AXLE DIESEL												3 AXLE DIESEL			
		MKT 331				MKT 332				RI 119				CB&Q 9948			
RUN NO.		12				1				10				28			
SPEED IN MPH.		10.5				41.2				48.0				13.9			
LOCOMOT. POSITION FOR SIMULTAN. STRESS		FIRST WHEEL AT															
		36.6' NORTH OF INTERSECTION				50.5' NORTH OF INTERSECTION				41.3' NORTH OF INTERSECTION				50.3' SOUTH OF INTERSECTION			
COL. NO. 1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOOR-BEAM NO.		SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
SECTION A-A	1	1.75	0.63	1.80	2.00	1.80	-0.34	1.90	1.90	2.30	0.06	2.40	2.35	2.10	0.25	2.15	1.79
	2	1.60	-0.12	1.65	1.83	1.60	-0.34	1.65	1.65	1.60	0.06	1.70	1.67	2.00	0.18	2.05	1.71
	3	1.65	0	1.65	1.83	1.75	0	1.75	1.75	1.80	-0.05	1.90	1.86	2.05	0.10	2.10	1.75
	4	1.45	0	1.45	1.61	1.90	0	1.90	1.90	1.65	0	1.65	1.62	2.00	0	2.00	1.67
	5	1.10	0.13	1.15	1.28	1.35	0	1.35	1.35	1.30	0	1.30	1.27	1.65	0	1.65	1.38
	6	1.00	0.13	1.05	1.17	1.05	-0.71	1.10	1.10	1.15	0.05	1.20	1.18	1.40	0	1.40	1.17
	7	0.65	0.51	0.70	0.78	0.70	-0.60	0.90	0.90	0.80	0.05	0.85	0.83	1.05	0	1.05	0.87
	8	0.55	0	0.55	0.61	0.50	-0.60	0.60	0.60	0.60	0.05	0.70	0.69	0.80	0	0.80	0.67
	9	0.30	0.72	0.35	0.39	0.35	-0.60	0.50	0.50	0.40	0.05	0.45	0.44	0.50	0	0.50	0.42
	10	0.20	0.72	0.25	0.28	0.20	-0.56	0.30	0.30	0.25	0	0.25	0.24	0.35	0	0.35	0.29
	11	0.10	0.72	0.15	0.17	0	-0.56	0.10	0.10	0.05	0.05	0.10	0.10	0.25	0	0.25	0.21
	12	0.05	0	0.05	0.06	0	0	0		0	0	0		0.05	0.50	0.10	0.08
	AVE.			0.90				1.00				1.04				1.20	
SECTION B-B	1	1.55	0	1.55	2.16	1.85	0	1.85	2.01	1.80	0	1.80	2.22	1.80	0	1.80	1.96
	2	1.65	0	1.65	2.29	1.85	0	1.85	2.01	1.80	0	1.80	2.22	1.80	0	1.80	1.96
	3	1.35	0	1.35	1.88	1.70	0	1.70	1.84	1.55	0	1.55	1.91	1.70	0	1.70	1.85
	4	1.45	0	1.45	2.02	1.90	0	1.90	2.06	1.65	0	1.65	2.04	2.00	0	2.00	2.28
	5	0.90	0	0.90	1.25	1.95	0	1.95	2.12	1.20	0	1.20	1.48	1.50	0	1.50	1.63
	6	0.80	0	0.80	1.11	1.10	0	1.10	1.19	1.05	0	1.05	1.27	1.10	0	1.10	1.20
	7	0.65	0	0.65	0.90	0.70	0	0.70	0.76	0.80	0	0.80	1.00	0.85	0	0.85	0.92
	8	0.45	0	0.45	0.63	0.45	0	0.45	0.49	0.55	0	0.55	0.68	0.60	0	0.60	0.65
	9	0.30	0	0.30	0.42	0.35	0	0.35	0.38	0.25	0	0.25	0.31	0.40	0	0.40	0.43
	10	0.20	0	0.20	0.28	0.15	0	0.15	0.16	0.15	0	0.15	0.19	0.25	0	0.25	0.27
	11	0.10	0	0.10	0.14	0	0	0		0	0	0		0.05	0	0.05	0.05
	12	0	0	0		0	0	0		-0.10	0	-0.10		0	0	0	
	13	-0.10	0	-0.10		-0.10	0	-0.10		-0.15	0	-0.15		-0.10	0	-0.10	
	AVE.			0.72				0.92				0.81				0.92	
AREA DESIGN FOR FLOORBEAMS 1-6 AT SECTION A-A																	
STATIC		2.87				2.87				3.04				3.20			
DYNAMIC		4.49				4.49				4.75				5.00			

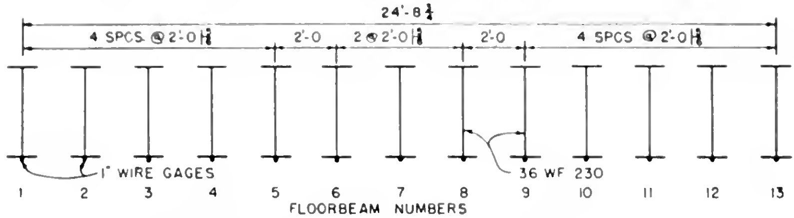
FOR NOTES SEE FIG. 54

FIG 56

MISSOURI-KANSAS-TEXAS RAILROAD BRIDGE TESTS

45'-0 WIDE FLANGE BEAM SPAN - BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



SECTION PERPENDICULAR TO ℄ OF TRACK

TEST TRAIN		SOUTHBOUND				NORTHBOUND											
		LOCOMOTIVE TYPE: 3 AXLE DIESEL															
		CB&Q 9948				MKT 153				FRISCO 2013				CB&Q 9948			
RUN NO.		4				29				7				2			
SPEED IN MPH.		61.3				2.4				49.4				64.2			
LOCOMOT. POSITION FOR SIMULTAN. STRESS		FIRST WHEEL AT															
		49.6' SOUTH OF INTERSECTION				53.3' NORTH OF INTERSECTION				73.4' NORTH OF INTERSECTION				6.8' NORTH OF INTERSECTION			
COL NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	FLOOR-BEAM NO.	SIMULT	TIME LAG	MAX	RATIO	SIMULT.	TIME LAG	MAX	RATIO	SIMULT	TIME LAG	MAX	RATIO	SIMULT	TIME LAG	MAX.	RATIO
SECTION A-A	1	2.15	0.09	2.35	1.85	2.10	-0.83	2.30	2.06	2.10	-0.09	2.20	1.95	1.95	-0.02	2.00	1.90
	2	2.05	0.08	2.20	1.74	2.05	-0.33	2.15	1.92	1.90	-0.09	2.00	1.77	1.80	-0.02	1.85	1.75
	3	2.30	0.03	2.35	1.85	2.00	-0.19	2.05	1.83	2.15	0	2.15	1.90	2.00	0	2.00	1.90
	4	2.15	0	2.15	1.70	1.80	0	1.80	1.61	1.85	0	1.85	1.64	1.75	0	1.75	1.66
	5	1.75	0	1.75	1.48	1.45	0	1.45	1.30	1.55	0.04	1.60	1.52	1.40	0	1.40	1.33
	6	1.50	-0.03	1.55	1.22	1.30	0	1.30	1.16	1.35	0	1.35	1.20	1.15	0.06	1.20	1.14
	7	1.05	-0.02	1.15	0.91	0.80	0	0.80	0.71	0.95	0	0.95	0.84	0.85	0.07	0.90	0.86
	8	0.65	-0.02	0.75	0.58	0.65	-1.76	0.70	0.63	0.65	-0.17	0.70	0.62	0.55	0.07	0.60	0.57
	9	0.40	-0.01	0.50	0.39	0.35	-1.76	0.40	0.36	0.40	-0.17	0.45	0.40	0.40	0	0.40	0.38
	10	0.25	0.05	0.35	0.28	0.20	-1.76	0.25	0.22	0.25	-0.17	0.30	0.27	0.30	0	0.30	0.29
	11	0.10	0.06	0.15	0.12	0.10	-1.76	0.15	0.13	0.05	-0.17	0.15	0.13	0.15	0	0.15	0.14
	12	0	0.06	0.05	0.04	0.05	-0.40	0.10	0.09	0	-0.17	-0.10		0.05	0	0.05	0.05
	AVE			1.27				1.12				1.13				1.05	
SECTION B-B	1	2.00	0	2.00	1.87	1.90	0	1.90	2.19	2.05	0	2.05	2.23	1.65	0	1.65	1.91
	2	2.20	0	2.20	2.05	2.10	0	2.10	2.41	2.00	0	2.00	2.17	1.80	0	1.80	2.10
	3	2.00	0	2.00	1.87	1.70	0	1.70	1.95	1.75	0	1.75	1.90	1.70	0	1.70	1.97
	4	2.15	0	2.15	2.00	1.80	0	1.80	2.07	1.85	0	1.85	2.00	1.75	0	1.75	2.03
	5	1.60	0	1.60	1.50	1.40	0	1.40	1.60	1.35	0	1.35	1.46	1.45	0	1.45	1.68
	6	1.20	0	1.20	1.12	1.00	0	1.00	1.15	1.15	0	1.15	1.25	1.00	0	1.00	1.16
	7	0.85	0	0.85	0.78	0.75	0	0.75	0.86	0.90	0	0.90	0.97	0.80	0	0.80	0.93
	8	0.60	0	0.60	0.56	0.50	0	0.50	0.57	0.60	0	0.60	0.65	0.55	0	0.55	0.64
	9	0.30	0	0.30	0.28	0.25	0	0.25	0.29	0.35	0	0.35	0.38	0.35	0	0.35	0.41
	10					0.10	0	0.10	0.12	0.10	0	0.10	0.11	0.20	0	0.20	0.23
	11	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0	0.10	0.11
	12	0	0	0	0	-0.05	0	-0.05		0	0	0	0	0	0	0	0
	13	-0.05	0	-0.05		-0.10	0	-0.10		-0.10	0	-0.10		-0.15	0	-0.15	
	AVE.			1.07				0.87				0.92				0.86	
AREA DESIGN FOR FLOORBEAMS 1-6 AT SECTION A-A																	
STATIC		3.20				2.99								3.20			
DYNAMIC		5.00				4.67								5.00			

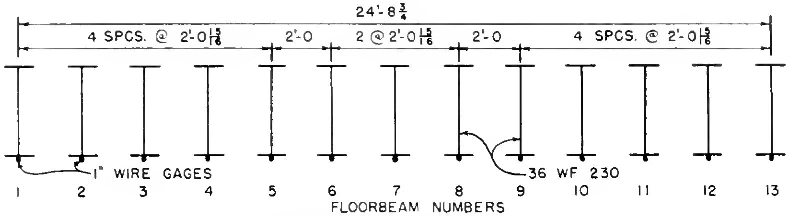
FOR NOTES SEE FIG. 54

FIG. 57

MISSOURI-KANSAS-TEXAS RAILROAD BRIDGE TESTS

45'-0 WIDE FLANGE BEAM SPAN-BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



SECTION PERPENDICULAR TO ℄ OF TRACK

TEST TRAIN		SOUTHBOUND — LOCOMOTIVE TYPE: 4-6-2 — MKT 411															
RUN NO.		15				16				26				27			
SPEED IN MPH.		6.0				6.7				7.7				8.4			
LOCOMOT. POSITION FOR SIMULTAN. STRESS		FIRST DRIVER AT 2.1' SOUTH OF INTERSECTION				2.9' SOUTH OF INTERSECTION				3.0' SOUTH OF INTERSECTION				6.0' SOUTH OF INTERSECTION			
COL. NO. 1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOORBEAM NO.		SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
SECTION A-A	1	2.45	1.01	2.70	2.18	2.65	0.35	2.80	2.09	2.60	0.45	2.85	2.11	2.70	0.52	2.80	2.17
	2	2.15	0.42	2.35	1.90	2.35	0.20	2.45	1.83	2.35	0.43	2.45	1.82	2.35	0.21	2.40	1.86
	3	2.25	0.15	2.30	1.86	2.45	0	2.45	1.83	2.45	0	2.45	1.82	2.35	0	2.35	1.82
	4	2.15	0	2.15	1.73	2.30	0	2.30	1.72	2.30	0	2.30	1.70	2.20	0	2.20	1.71
	5	1.60	0	1.60	1.29	1.80	0	1.80	1.34	1.85	0	1.85	1.37	1.70	0	1.70	1.32
	6	1.40	0	1.40	1.13	1.60	0	1.60	1.19	1.50	0	1.50	1.11	1.45	0	1.45	1.12
	7	0.95	0	0.95	0.77	1.05	0	1.05	0.78	1.10	0	1.10	0.81	1.00	-0.17	1.05	0.82
	8	0.65	0	0.65	0.52	0.75	0	0.75	0.56	0.75	0	0.75	0.56	0.75	0	0.75	0.58
	9	0.40	0	0.40	0.32	0.45	0	0.45	0.34	0.50	0	0.50	0.37	0.40	0	0.40	0.31
	10	0.25	0	0.25	0.20	0.25	0	0.25	0.19	0.30	0	0.30	0.22	0.25	0	0.25	0.19
	11	0.10	0	0.10	0.08	0.10	0	0.10	0.08	0.15	0	0.15	0.11	0.15	0	0.15	0.12
	12	0	0	0	0	0		0.05	0.04	0	-0.02	0.05	0.04	0		-0.05	
	AVE.			1.24				1.34				1.35				1.29	
SECTION B-B	1	2.25	0	2.25	2.14	2.40	0	2.40	2.20	2.40	0	2.40	2.20	2.45	0	2.45	2.23
	2	2.35	0	2.35	2.22	2.55	0	2.55	2.34	2.45	0	2.45	2.22	2.45	0	2.45	2.23
	3	2.05	0	2.05	1.95	2.05	0	2.05	1.88	2.10	0	2.10	1.93	2.05	0	2.05	1.86
	4	2.15	0	2.15	2.05	2.30	0	2.30	2.11	2.30	0	2.30	2.11	2.20	0	2.20	2.00
	5	1.35	0	1.35	1.29	1.40	0	1.40	1.27	1.70	0	1.70	1.56	1.60	0	1.60	1.40
	6	1.25	0	1.25	1.19	1.25	0	1.25	1.15	1.25	0	1.25	1.15	1.25	0	1.25	1.14
	7	1.00	0	1.00	0.95	1.00	0	1.00	0.92	1.00	0	1.00	0.92	1.05	0	1.05	
	8	0.70	0	0.70	0.67	0.60	0	0.60	0.55	0.60	0	0.60	0.55	0.70	0	0.70	0.64
	9	0.40	0	0.40	0.38	0.40	0	0.40	0.37	0.35	0	0.35	0.32	0.45	0	0.45	0.41
	10	0.25	0	0.25	0.24	0.20	0	0.20	0.18	0.20	0	0.20	0.18	0.25	0	0.25	0.23
	11	0.10	0	0.10	0.10	0.10	0	0.10	0.09	0.05	0	0.05	0.05	0.05	0	0.05	0.05
	12	0	0	0	0	0	0	0	0	-0.10	0	-0.10		-0.10	0	-0.10	
	13	-0.15	0	-0.15		-0.10	0	-0.10		-0.10	0	-0.10		-0.15	0	-0.15	
	AVE			1.05				1.09				1.09				1.10	
AREA DESIGN FOR FLOORBEAMS 1-6 AT SECTION A-A																	
STATIC		4.04				4.04				4.04				4.04			
DYNAMIC		7.12				7.12				7.12				7.12			

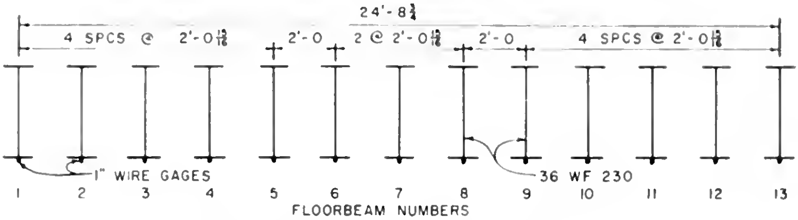
FOR NOTES SEE FIG. 54

FIG 58

MISSOURI - KANSAS - TEXAS RAILROAD BRIDGE TESTS

45'-0 WIDE FLANGE BEAM SPAN - BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



SECTION PERPENDICULAR TO ℄ OF TRACK

TEST TRAIN		SOUTHBOUND															
		LOCOMOTIVE TYPE 4-6-2															
		MKT 411															
RUN NO.		13				19				17				18			
SPEED IN MPH		11 4				19 5				19 7				23.0			
LOCOMOT POSITION FOR SIMULTAN STRESS		FIRST DRIVER AT															
		7 0' SOUTH OF INTERSECTION				3 2' SOUTH OF INTERSECTION				2 7' SOUTH OF INTERSECTION				3 1' SOUTH OF INTERSECTION			
COL NO 1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOOR-BEAM NO		SIMULT	TIME LAG	MAX	RATIO	SIMULT	TIME LAG	MAX	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT	TIME LAG	MAX.	RATIO
SECTION A-A	1	2 75	0 20	2 85	1 99	2 40	0 28	2 85	2 10	2 60	0 29	2 80	2 12	2 85	0 04	2.90	2 12
	2	2 45	0 20	2 50	1 75	2 20	0 28	2 45	1 81	2 30	0 10	2 40	1 82	2 45	0 04	2 50	1 82
	3	2 55	-0 19	2 60	1 82	2 30	0 18	2 35	1 74	2 40	0	2 40	1 82	2 55	0	2 55	1 86
	4	2 35	0	2 35	1 64	2 10	0	2 10	1 56	2 20	0	2 20	1 67	2 30	0	2 30	1 68
	5	1 85	-0 19	1 90	1 35	1 75	0	1 75	1 30	1 70	0	1 70	1 29	1 80	0	1 80	1 31
	6	1 60	-0 19	1 65	1 15	1 50	0	1 50	1 11	1 50	0	1 50	1 14	1 55	0	1 55	1 13
	7	1 20	0	1 20	0 84	1 05	0	1 05	0 78	1 00	0	1 00	0 76	1 10	0	1 10	0 80
	8	0 85	0	0 85	0 59	0 70	0	0 70	0 52	0 75	0	0 75	0 57	0 75	0	0 75	0 55
	9	0 60	0	0 60	0 42	0 95	0	0 95	0 70	0 50	0	0 50	0 38	0 50	0	0 50	0 36
	10	0 35	-0 10	0 40	0 28	0 25	0 07	0 30	0 22	0 30	0	0 30	0 23	0 25	0 17	0 30	0.22
	11	0 20	0	0 20	0 14	0 15	0	0 15	0 11	0 15	0	0 15	0 11	0 15	0	0 15	0 11
	12	0 05	0 60	0 10	0 07	0 05	0 16	0 10	0 07	0 05	0 30	0 10	0 08	0	0.18	0 05	0 04
	AVE			1 43				1 35				1 32				1 37	
SECTION B-B	1	2 45	0	2 45	2 13	2 20	0	2 20	2 14	2 35	0	2 35	2 18	2 55	0	2 55	2 32
	2	2 45	0	2 45	2 13	2 30	0	2 30	2 23	2 35	0	2 35	2 18	2 60	0	2 60	2 36
	3	2 10	0	2 10	1 83	1 95	0	1 95	1 89	2 05	0	2 05	1 90	2 20	0	2 20	2 00
	4	2 35	0	2 35	2 04	2 10	0	2 10	2 04	2 20	0	2 20	2 04	2 30	0	2 30	2 09
	5	1 40	0	1 40	1 22	1 50	0	1 50	1 46	1 55	0	1 55	1 43	1 50	0	1 50	1 36
	6	1 35	0	1 35	1 17	1 20	0	1 20	1 16	1 25	0	1 25	1 16	1 20	0	1 20	1 09
	7	1 15	0	1 15	1 00	1 00	0	1 00	0 97	1 00	0	1 00	0 93	1 00	0	1 00	0 91
	8	0 80	0	0 80	0 70	0 70	0	0 70	0 68	0 70	0	0 70	0 65	0 65	0	0 65	0 59
	9	0 50	0	0 50	0 43	0 35	0	0 35	0 34	0 40	0	0 40	0 37	0 35	0	0 35	0 32
	10	0 35	0	0 35	0 30	0 20	0	0 20	0 19	0 25	0	0 25	0 23	0 20	0	0 20	0 18
	11	0 15	0	0 15	0 10	0 05	0	0 05	0 05	0 15	0	0 10	0 09	0 05	0	0 05	0 05
	12	0	0	0	0	-0.05	0	-0.05		0	0	0	0	-0.10	0	-0.10	
	13	-0.10	0	-0.10		-0.15	0	-0.15		-0.15	0	-0.15		-0.15	0	-0.15	
	AVE.			1 15				1 03				1 08				1 10	
AREA DESIGN FOR FLOORBEAMS 1-6 AT SECTION A-A																	
STATIC		4.04				4.04				4.04				4.04			
DYNAMIC		7.12				7.12				7.12				7.12			

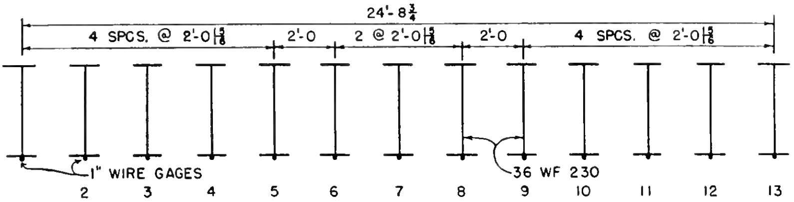
FOR NOTES SEE FIG 54

FIG. 59

MISSOURI-KANSAS-TEXAS RAILROAD BRIDGE TESTS

45'-0 WIDE FLANGE BEAM SPAN-BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



FLOORBEAM NUMBER

SECTION PERPENDICULAR TO ℄ OF TRACK

TEST TRAIN		SOUTHBOUND															
		LOCOMOTIVE TYPE: 4-6-2															
		MKT 411															
RUN NO.		20				21				22				23			
SPEED IN MPH.		28.1				35.4				37.5				46.7			
LOCOMOT. POSITION FOR SIMULTAN. STRESS		FIRST DRIVER AT															
		2.3' SOUTH OF INTERSECTION				9.1' SOUTH OF INTERSECTION				2.4' SOUTH OF INTERSECTION				5.9' SOUTH OF INTERSECTION			
COL. NO. 1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FLOOR-BEAM NO.		SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
SECTION A-A	1	2.75	0.23	2.95	2.11	3.45	0.02	3.50	2.21	2.75	0.09	2.80	1.94	3.45	0.01	3.50	2.22
	2	2.45	0.06	2.60	1.86	2.85	0	2.85	1.80	2.45	0	2.45	1.70	2.80	0	2.80	1.77
	3	2.55	0	2.55	1.82	2.70	0	2.70	1.71	2.55	0	2.55	1.77	2.85	0	2.85	1.80
	4	2.30	0	2.30	1.64	2.45	0	2.45	1.55	2.45	0	2.45	1.70	2.50	0	2.50	1.58
	5	1.90	0	1.90	1.36	1.95	0	1.95	1.23	2.05	0	2.05	1.42	1.95	0.01	2.00	1.27
	6	1.60	0	1.60	1.14	1.70	0	1.70	1.07	1.70	0	1.70	1.18	1.65	0	1.65	1.04
	7	1.10	0	1.10	0.79	1.25	0	1.25	0.79	1.25	0	1.25	0.87	1.45	0	1.45	0.92
	8	0.75	0	0.75	0.54	0.95	0	0.95	0.60	0.90	0	0.90	0.62	0.90	0	0.90	0.57
	9	0.50	0	0.50	0.36	0.55	-0.06	0.65	0.41	0.55	0	0.55	0.38	0.55	0.01	0.60	0.38
	10	0.30	0	0.30	0.21	0.25	-0.06	0.40	0.25	0.30	-0.02	0.35	0.24	0.30	0.01	0.35	0.22
	11	0.15	-0.19	0.20	0.14	0.15	-0.06	0.30	0.19	0.15	-0.02	0.20	0.14	0.15	0.01	0.20	0.13
	12	0.05	-0.19	0.10	0.07	0.10	0.22	0.20	0.13	0	-0.02	0.05	0.03	0.10	0	0.10	0.06
	AVE.			1.40				1.58				1.44				1.58	
SECTION B-B	1	2.50	0	2.50	2.21	2.70	0	2.70	2.18	2.65	0	2.65	2.19	2.85	0	2.85	2.34
	2	2.60	0	2.60	2.30	2.85	0	2.85	2.30	2.70	0	2.70	2.23	2.90	0	2.90	2.38
	3	2.20	0	2.20	1.95	2.20	0	2.20	1.77	2.25	0	2.25	1.86	2.35	0	2.35	1.93
	4	2.30	0	2.30	2.04	2.45	0	2.45	1.97	2.45	0	2.45	2.02	2.50	0	2.50	2.05
	5	1.65	0	1.65	1.46	1.80	0	1.80	1.45	1.85	0	1.85	1.53	1.75	0	1.75	1.44
	6	1.25	0	1.25	1.11	1.85	0	1.85	1.49	1.35	0	1.35	1.12	1.35	0	1.35	1.11
	7	1.00	0	1.00	0.90	1.10	0	1.10		1.15	0	1.15	0.95	1.10	0	1.10	0.90
	8	0.60	0	0.60	0.53	0.65	0	0.65	0.52	0.75	0	0.75	0.62	0.65	0	0.65	0.53
	9	0.40	0	0.40	0.35	0.40	0	0.40	0.32	0.45	0	0.45	0.37	0.40	0	0.40	0.33
	10	0.15	0	0.15	0.13	0.25	0	0.25	0.20	0.25	0	0.25	0.21	0.25	0	0.25	0.21
	11	0.10	0	0.10	0.09	0.05	0	0.05	0.04	0.05	0	0.05	0.04	0.05	0	0.05	0.04
	12	0	0	0	0	0	0	0	0	-0.05	0	-0.05		-0.10	0	-0.10	
	13	-0.10	0	-0.10		-0.20	0	-0.20		-0.15	0	-0.15		-0.15	0	-0.15	
	AVE.			1.13				1.24				1.21				1.22	
AREA DESIGN FOR FLOORBEAMS 1-6 AT SECTION A-A																	
STATIC		4.04				4.04				4.04				4.04			
DYNAMIC		7.12				7.12				7.12				7.12			

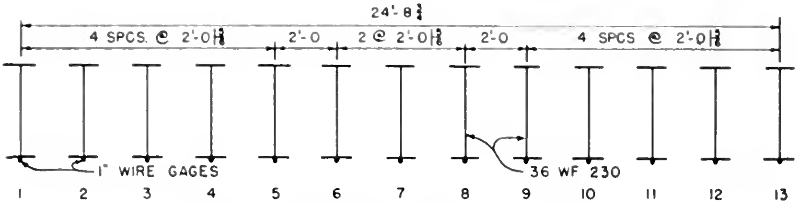
FOR NOTES SEE FIG. 54

FIG 60

MISSOURI - KANSAS - TEXAS RAILROAD BRIDGE TESTS

45'-0 WIDE FLANGE BEAM SPAN-BALLASTED STEEL PLATE FLOOR

RECORDED STRESSES IN LONGITUDINAL FLOORBEAMS



SECTION PERPENDICULAR TO ℄ OF TRACK

TEST TRAIN		SOUTHBOUND															
		LOCOMOTIVE TYPE: 4-6-2								LOCOMOTIVE TYPE: 2-8-2							
		MKT 411								RI 2616							
RUN NO.		24				25				6				5			
SPEED IN MPH.		49.2				55.0				16.9				22.4			
LOCOMOT. POSITION FOR SIMULTAN. STRESS		FIRST DRIVER AT 4.6' SOUTH OF INTERSECTION				8.9' SOUTH OF INTERSECTION				12.5' SOUTH OF INTERSECTION				10.5' SOUTH OF INTERSECTION			
COL NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	FLOOR-BEAM NO.	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO	SIMULT.	TIME LAG	MAX.	RATIO
SECTION A-A	1	3.35	0.02	3.40	2.25	3.40	0.02	3.45	2.17	3.20	-0.03	3.30	1.94	3.70	0	3.70	2.00
	2	2.85	0.03	2.90	1.92	3.00	0	3.00	1.89	3.00	-0.03	3.05	1.80	3.35	0	3.35	1.81
	3	2.85	0	2.85	1.89	2.95	0	2.95	1.85	3.15	0	3.15	1.85	3.50	0	3.50	1.89
	4	2.50	0	2.50	1.66	2.65	0	2.65	1.67	2.75	0	2.75	1.62	2.95	0	2.95	1.59
	5	1.90	0	1.90	1.26	2.00	0	2.00	1.26	2.30	0	2.30	1.35	2.50	0	2.50	1.35
	6	1.50	-0.02	1.55	1.03	1.70	0	1.70	1.07	1.95	0	1.95	1.15	2.10	0.14	2.15	1.16
	7	1.10	0	1.10	0.73	1.20	0.02	1.25	0.79	1.35	-0.03	1.40	0.82	1.40	-0.02	1.55	0.84
	8	0.70	0.17	0.75	0.50	0.85	0.02	0.90	0.57	0.95	-0.03	1.00	0.59	0.95	-0.02	1.10	0.59
	9	0.45	0.17	0.55	0.36	0.55	0.02	0.60	0.38	0.60	-0.03	0.70	0.41	0.55	-0.02	0.65	0.35
	10	0.15	0.17	0.30	0.20	0.25	0.02	0.30	0.19	0.35	-0.03	0.40	0.24	0.30	-0.02	0.35	0.19
	11	0.05	0.17	0.20	0.13	0.10	0.02	0.20	0.13	0.20	-0.03	0.25	0.15	0.20	-0.02	0.25	0.14
	12	0	0.17	0.10	0.07	0.05	-0.02	0.10	0.06	0.05	-0.03	0.15	0.09	0.10	-0.02	0.15	0.08
	AVE.			1.51				1.59				1.70				1.85	
SECTION B-B	1	3.20	0	3.20	2.50	3.15	0	3.15	2.32	2.90	0	2.90	2.03	3.55	0	3.55	2.34
	2	3.15	0	3.15	2.45	3.10	0	3.10	2.28	3.00	0	3.00	2.13	3.35	0	3.35	2.20
	3	2.55	0	2.55	1.99	2.60	0	2.60	1.91	2.60	0	2.60	1.84	2.95	0	2.95	1.94
	4	2.50	0	2.50	1.95	2.65	0	2.65	1.95	2.75	0	2.75	1.95	2.95	0	2.95	1.94
	5	1.75	0	1.75	1.37	2.00	0	2.00	1.47	2.15	0	2.15	1.53	2.20	0	2.20	1.45
	6	1.35	0	1.35	1.05	1.60	0	1.60	1.18	1.80	0	1.80	1.28	1.90	0	1.90	1.25
	7	1.05	0	1.05	0.82	1.25	0	1.25	0.92	1.40	0	1.40	1.00	1.40	0	1.40	
	8	0.70	0	0.70	0.55	0.75	0	0.75	0.55	1.05	0	1.05		1.00	0	1.00	0.66
	9	0.40	0	0.40	0.31	0.45	0	0.45	0.33	0.55	0	0.55	0.39	0.45	0	0.45	0.29
	10	0.15	0	0.15	0.12	0.20	0	0.20	0.15	0.25	0	0.25	0.18	0.20	0	0.20	0.13
	11	0.05	0	0.05	0.04	0.10	0	0.10	0.07	0.05	0	0.05	0.04	0		0	0
	12	-0.10	0	-0.10		-0.05	0	-0.05		0		0	0	0		0	0
	13	-0.15	0	-0.15		-0.10	0	-0.10		-0.15	0	-0.15		-0.15	0	-0.15	
	AVE.			1.28				1.36				1.41				1.52	
AREA DESIGN FOR FLOORBEAM 1-6 AT SECTION A-A																	
STATIC		4.04				4.04				4.99				4.99			
DYNAMIC		7.12				7.12				8.80				8.80			

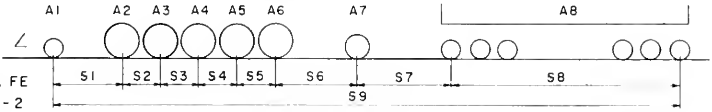
FOR NOTES SEE FIG. 54

TABLE I

BRIDGE TESTS ON FLOORBEAMS

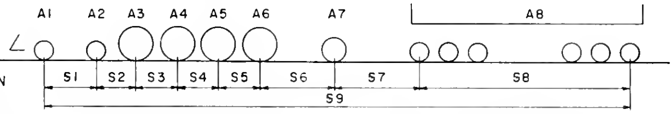
LOCOMOTIVE DATA

SANTA FE
2-10-2



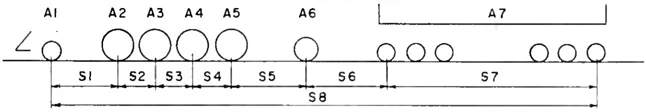
RAILROAD & LOCO NUMBERS	AXLE WEIGHTS - KIPS								AXLE SPACINGS - FEET								
	A1	A2	A3	A4	A5	A6	A7	A8	S1	S2	S3	S4	S5	S6	S7	S8	S9
B&O 6181-6203	31 6	69 8	69 6	69 1	69 6	69 1	57 7	240	9'-9	5'-7	5'-7	5'-7	5'-7	10'-10	13'-7$\frac{7}{8}$	33'-4	89'-10$\frac{7}{8}$

MOUNTAIN
4-8-2



RAILROAD & LOCO NUMBERS	AXLE WEIGHTS - KIPS								AXLE SPACINGS - FEET								
	A1	A2	A3	A4	A5	A6	A7	A8	S1	S2	S3	S4	S5	S6	S7	S8	S9
NYC 2744-2884	29 2	29 2	61 4	61 4	61 4	61 4	60 9	237	7'-6	5'-8	6'-0	6'-0	6'-0	10'-10	12'-4	30'-3	84'-7
NYC 3015	35 2	35 2	65 5	65 5	65 5	65 5	56 1	302	7'-2	6'-1	6'-4	6'-4	6'-4	10'-10	14'-1$\frac{1}{2}$	38'-9	95'-11$\frac{1}{2}$
B&O 5653-5661	38 9	38 9	67 4	68 5	67 5	67.7	68 9	300	7'-4	5'-7	6'-5	6'-5	6'-5	12'-0	12'-5	36'-1	92'-8
B&O 5589	32 5	32 5	63 5	65 0	62 5	64 0	55 0	291	7'-2	5'-9	6'-1	6'-1	6'-1	9'-6	14'-9$\frac{1}{4}$	32'-8	88'-1$\frac{1}{4}$

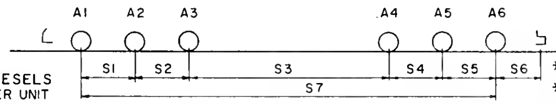
MIKADO
2-8-2



RAILROAD & LOCO. NUMBERS	AXLE WEIGHTS - KIPS							AXLE SPACINGS - FEET							
	A1	A2	A3	A4	A5	A6	A7	S1	S2	S3	S4	S5	S6	S7	S8
NYC 2277 & 2282	30 4	63 1	63 1	63 1	63 1	59 6	223	9'-8	5'-6	5'-6	5'-6	10'-10	11'-8	30'-3	78'-11
NYC 1713	20 4	56 4	56 4	56 4	56 4	54 6	147	9'-4	5'-7	5'-7	5'-7	10'-10	11'-6$\frac{1}{2}$	23'-6*	71'-11
MKT 910	25 0	59 9	59 9	59 9	59 9	59 5	194	9'-2	5'-6	5'-6	5'-6	10'-9	11'-6	24'-7*	72'-6
B&O 4447-4486	22 7	60 1	62 1	62 8	62 0	57 7	173	9'-1	5'-7	5'-7	5'-7	9'-3	13'-5$\frac{3}{4}$	25'-8*	74'-2$\frac{3}{4}$
SOU 4905 & 6623	25 5	59 7	58 9	60 2	60 7	61 0	192	9'-4	5'-7	5'-7	5'-7	10'-10	11'-3$\frac{1}{2}$	23'-6*	71'-8$\frac{1}{2}$
CRI&P 2616	28 7	62 3	62 3	62 3	62 3	58 4	155	9'-0	5'-8	5'-8	5'-8	9'-4	12'-0	25'-8*	73'-0

* 4 AXLE TENDER

3-AXLE DIESELS
2000 HP PER UNIT



* 2250 HP PER UNIT

** 1500 HP PER UNIT

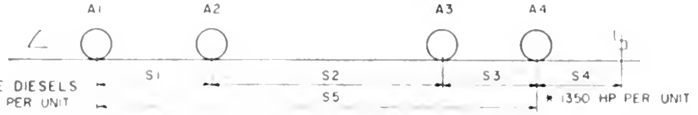
RAILROAD & LOCO. NUMBERS	AXLE WEIGHTS - KIPS						AXLE SPACINGS - FEET						
	A1	A2	A3	A4	A5	A6	S1	S2	S3	S4	S5	S6	S7
NYC 3202 **	56 4	54 6	56 4	56 4	54 6	56 4	7'-9	7'-9	15'-0	7'-9	7'-9	6'-9	46'-0
NYC 4000-4034 *	54 0	52 2	54 0	54 0	52 2	54 0	7'-0$\frac{1}{2}$	7'-0$\frac{1}{2}$	28'-11	7'-0$\frac{1}{2}$	7'-0$\frac{1}{2}$	6'-5$\frac{1}{2}$	57'-1
NYC 4200-4302	51 1	52 7	51 1	51 1	52 7	51 1	7'-9	7'-9	18'-8	7'-9	7'-9	6'-11	49'-8
MKT 107 *	54 8	54 8	54 8	54 8	54 8	54 8	7'-0$\frac{1}{2}$	7'-0$\frac{1}{2}$	28'-11	7'-0$\frac{1}{2}$	7'-0$\frac{1}{2}$	6'-5$\frac{1}{2}$	57'-1
MKT 153 & 154 *	52 7	52.7	52 7	52 7	52 7	52 7	7'-9	7'-9	18'-8	7'-9	7'-9	6'-11	49'-8
B&O 62-65	54 3	51.3	54 3	52.1	49 2	52 1	7'-0$\frac{1}{2}$	7'-0$\frac{1}{2}$	28'-11	7'-0$\frac{1}{2}$	7'-0$\frac{1}{2}$	6'-5$\frac{1}{2}$	57'-1
CRI&P 632-635	52 1	50 4	52 1	52 1	50 4	52.1	7'-0$\frac{1}{2}$	7'-0$\frac{1}{2}$	28'-11	7'-0$\frac{1}{2}$	7'-0$\frac{1}{2}$	6'-5$\frac{1}{2}$	57'-1
CB&Q 9948	55 9	50.9	55.9	55.9	57.9	55.9	7'-0$\frac{1}{2}$	7'-0$\frac{1}{2}$	28'-11	7'-0$\frac{1}{2}$	7'-0$\frac{1}{2}$	6'-5$\frac{1}{2}$	57'-1

TABLE 2

BRIDGE TESTS ON FLOORBEAMS

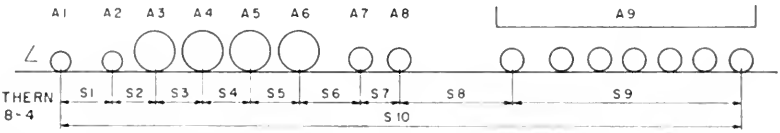
LOCOMOTIVE DATA

2-AXLE DIESELS
1500 HP PER UNIT



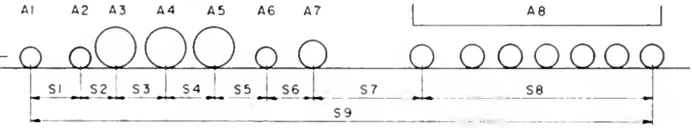
RAILROAD & LOCO NUMBERS	AXLE WEIGHTS KIPS				AXLE SPACINGS - FEET				
	A1	A2	A3	A4	S1	S2	S3	S4	S5
NYC 3501	62.3	62.3	62.3	62.3	9'-0	21'-0	9'-0	5'-6	39'-0
MKT 331-333	60.0	60.0	60.0	60.0	9'-4	17'-10	9'-4	6'-9	36'-6
MKT 1506-1539	60.3	60.3	60.3	60.3	9'-0	22'-0	9'-0	7'-11½	40'-0
B&O 82-85	60.2	60.2	61.8	61.8	9'-0	21'-0	9'-0	5'-6⅜	39'-0
B&O 103 *	57.5	57.5	57.3	57.3	9'-0	18'-3	9'-0	4'-0	36'-3
SOU 4130-6806	59.5	59.5	61.4	61.4	9'-0	21'-0	9'-0	5'-6	39'-0
SOU 4117 *	61.7	61.7	62.0	62.0	9'-0	18'-3	9'-0	4'-4	36'-3
CRI&P 103-119	57.2	57.2	57.2	57.2	9'-0	21'-0	9'-0	5'-6	39'-0
CRI&P 146	56.7	56.7	56.7	56.7	9'-4	17'-10	9'-4	6'-10	36'-6

NORTHERN
4-8-4



RAILROAD & LOCO NUMBERS	AXLE WEIGHTS - KIPS									AXLE SPACINGS - FEET									
	A1	A2	A3	A4	A5	A6	A7	A8	A9	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
NYC 6005-6021	45.7	45.7	68.8	68.8	68.8	68.8	52.3	52.3	34.0	7'-4	6'-3	6'-10	6'-10	6'-10	8'-10	5'-6	16'-1½	32'-8	97'-2½

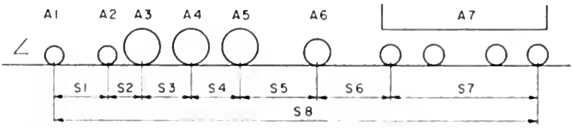
HUDSON
4-6-4



RAILROAD & LOCO NUMBERS	AXLE WEIGHTS - KIPS								AXLE SPACINGS - FEET								
	A1	A2	A3	A4	A5	A6	A7	A8	S1	S2	S3	S4	S5	S6	S7	S8	S9
NYC 5267 & 5408-5454	32.3	32.3	66.5	66.5	66.5	42.6	54.6	34.0	7'-2	5'-2	7'-0	7'-0	7'-4	6'-8	15'-5⅞	32'-8	88'-5⅞
NYC 5234-5261 & 5295-5394	32.6	32.6	63.9	63.9	63.9	46.5	56.3	24.3	7'-2	5'-2	7'-0	7'-0	7'-4	6'-8	12'-6½	30'-9 *	83'-7½

* 6-AXLE TENDER

PACIFIC
4-6-2



RAILROAD & LOCO NUMBERS	AXLE WEIGHTS - KIPS							AXLE SPACINGS - FEET							
	A1	A2	A3	A4	A5	A6	A7	S1	S2	S3	S4	S5	S6	S7	S8
NYC 4441-4596	24.5	24.5	58.5	58.5	58.5	49.5	12.6	6'-8	4'-10	6'-3	6'-3	9'-7	11'-10½	20'-10	66'-3½
NYC 4856	24.5	24.5	59.3	59.3	59.3	49.0	14.0	6'-8	4'-11	7'-0	7'-0	10'-11	10'-6	21'-0	68'-0
MKT 411	28.0	28.0	54.0	59.1	54.0	58.0	20.2	6'-8	4'-8	6'-6	6'-6	10'-11	10'-10¼	25'-0	71'-1¼
CRI&P 890-928	23.2	23.2	50.5	50.5	50.5	45.2	12.1	6'-4	4'-8	6'-6	6'-6	10'-2	11'-0	20'-6	65'-8
C&NW 505-579	25.0	25.0	51.4	51.4	51.4	45.0	16.6	6'-10	4'-10	6'-9	6'-9	9'-6	11'-3¾	21'-0	66'-11¾

TABLE 3

BRIDGE TESTS ON TRANSVERSE FLOORBEAMS

STATIC STRESSES AND "K" DISTRIBUTION FACTORS

NUMBER OF TRACKS	RAILROAD - LENGTH AND TYPE OF SPAN	LENGTH, SIZE AND SPACING OF FLOORBEAMS TYPE OF FLOOR	REFER TO FIGURE NUMBERS	TYPE OF LOCOMOTIVE	SPEED - MPH	AVERAGE RECORDED MAXIMUM STATIC STRESS - KSI	CALCULATED MAXIMUM STATIC STRESS KSI	** K_E	MAXIMUM VARIATION FROM AVERAGE RECORDED MAXIMUM STATIC STRESS-PERCENT	REMARKS
1	2	3	4	5	6	7	8	9	10	11
SINGLE	NEW YORK CENTRAL 70'-0 GIRDER SPAN TRACK NO.1	15'-7¾ 15 I 81.3 2'-1¾ ½ STEEL PLATE CONCRETE LINED	11 & 12	3-AXLE DIESEL	5.4	3.12	4.98	0.71	26	DIAPHRAGMS CONNECTED
					6.5	3.11		0.70	28	
					6.6	3.06		0.69	25	
					7.5	3.09		0.70	30	
					7.6	3.18		0.72	28	
			11 & 13		4.2	3.36		0.76	23	DIAPHRAGMS DISCONNECTED
					4.6	3.28		0.74	22	
					4.7	3.24		0.73	20	
					5.5	3.35		0.76	21	
					5.7	3.33		0.75	23	
					5.7	3.41		0.77	21	
					6.0	3.39		0.77	23	
	NYC 70'-0 GIRD. SPAN TRACK NO.3	13'-6;12 I 70.2'-1¾ ⅜ STEEL PLATE TIMBER STRG.	14-18	3-AXLE	17.7	4.62	5.20	1.00	43	NO DIAPHRAGMS
				4-8-4	4.7	6.22	6.84	1.02	35	
				0-8-0	18.8	5.91	6.94	0.96	34	
	NEW YORK CENTRAL 39'-0¼ GIRDER SPAN	11'-3;15 I 50;1'-4 3/16 3/16 STEEL PLATE CONC. LINED 2'-0 BALLAST	19-24	3-AXLE DIESEL	6.1	1.42	3.29	0.49	59	NO DIAPHRAGMS
					6.9	1.21	2.91	0.47	57	
				4-8-4	4.8	1.75	4.31	0.46	54	
				2-8-4	6.4	1.98			51	
				4-6-4	6.3	1.64	4.07	0.45	51	
	SOUTHERN RAILWAY 58'-4½ GIRDER SPAN	17'-6 18 WF 85 1'-11¾ 9/16 STEEL PLATE 11" BALLAST	5-9	2-AXLE DIESEL	4.2	3.19	3.80	0.95	36	TWO LINES OF DIAPHRAGMS
					5.2	3.19		0.95	36	
					6.0	3.18		0.95	30	
					6.1	2.80	3.76	0.84	19	
				2-8-2	3.0	4.48	6.00	0.84	31	
					3.1	4.54		0.85	34	
					4.0	4.64		0.87	27	
					4.1	4.59		0.86	27	
					4.6	4.35		0.86	36	
					8.0	4.58		0.86	30	
	MISSOURI KANSAS TEXAS 97'-2⅞ GIRDER SPAN	19'-3 24 WF 74 1'-7⅝ ⅜ STEEL PLATE 1'-3 MIN. BALLAST	35-38	2-AXLE DIESEL	3.5	2.61	2.96	0.99	38	TWO LINES OF DIAPHRAGMS
					5.6	2.56	2.99	0.96	42	
				3-AXLE	11.0	2.13	3.16	0.76	27	
				2-8-2	3.3	3.64	5.06	0.81	22	
					3.4	3.55		0.79	24	
					3.7	3.47		0.77	27	
					3.9	3.36		0.75	31	
			39-41		4.6	3.86		0.86	24	AVERAGE OF 18 FLOORBEAMS
					5.0	3.64		0.81	25	
					5.1	3.65		0.81	29	
					5.2	3.73		0.83	22	
					5.7	3.69		0.82	17	
	C & O 100' GIRDER SPAN	17'-6;18WF 55 1'-6½ ⅜ W.I. PLATE 5" BALLAST	*	2-8-2	5.9	6.90	7.50	1.04	19	SINGLE LINE DIAPHRAGMS
					7.2	7.16	7.26	1.11	18	
					9.2	7.07	6.90	1.15	16	
DOUBLE	BALTIMORE & OHIO 74'-7⅜ GIRDER SPAN	31'-8 30 WF 172 2'-10⅜ 6"R.C SLAB 1'-4½ MIN. BALLAST	29-32	2-AXLE	4.2	1.66	3.23	0.64	26	NO DIAPHRAGMS
				3-AXLE DIESEL	4.6	1.73	3.66	0.59	22	
					5.4	1.75		0.60	14	
				4-8-2	4.3	2.54	5.06	0.63	17	
					4.6	2.53		0.63	19	
					4.8	2.51		0.62	18	
	NYC 93'-5 GIRDER SPAN	30'-6 28½ BG 175 1'-10½ OPEN TIMBER FLOOR	25-28	4-8-2	3.8	3.01	3.17	1.19	25	SHORT STRINGERS UNDER EACH RAIL SERVE AS DIAPHRAGMS
					5.4	3.23		1.27	19	
				2-8-2	1.9	3.00	3.56	1.05	23	
					9.4	2.98		1.05	19	

* SEE AREA PROCEEDINGS, VOL 49, 1948, PAGE 279

NOTE: DEPTH OF BALLAST AS SHOWN IS REFERED TO BOTTOM OF TIE

** K = 1⅛ FOR SINGLE TRACK, 1¼ FOR DOUBLE TRACK.

Passenger Ride Comfort on Curved Track

Report of the Joint Committee on Relation Between Track and Equipment of the Engineering and Mechanical Divisions, Association of American Railroads, in Collaboration with AREA Committees 5—Track, and 28—Clearances

CONTENTS

Passenger Ride Comfort on Curved Track

Report of the Joint Committee on Relation Between Track and Equipment of the Engineering and Mechanical Divisions, AAR, in Collaboration with AREA Committees 5—Track, and 28—Clearances

A. DIGEST

This report gives the results of tests carried out to obtain the necessary data for making recommendations for the permissible speed on curves and the length of transition curves for passenger comfort, and for establishing clearance requirements on curved track. Present speed limitations were established in 1914 by mathematical analysis, personal observation and experience. Since that time changes have been made in track, increases in operating speeds, and the introduction of modern-type passenger equipment with markedly different truck and springing arrangements. In addition, electrical measuring equipment is now available permitting a more exact and scientific evaluation of quantities related to ride comfort.

The first test was run on the Louisville & Nashville, May 10, 1950, using the Chesapeake & Ohio track inspection car and making use of 20 observers to obtain a correlation between passenger reaction and the amount of unbalanced centrifugal force on curves as determined by measurements of the lateral acceleration. Results of this test indicated the importance of the roll of the car body in reducing the effective elevation of the track insofar as passenger comfort was concerned. Accordingly, measurements were made in a second test on the Kansas City Southern on June 20, 1951, also using passenger observers and, in addition, a specially developed gyroscope and recorder to show the angle of the car body from the vertical. From the results of these tests it was possible to establish a very satisfactory relationship between passenger reaction and the amount of lateral acceleration so that in subsequent tests it was not necessary to use passenger observers.

To obtain data on the various types of modern passenger cars being used, running tests were subsequently made on the New York, New Haven & Hartford, the Lackawanna, the Pennsylvania, the Milwaukee, the Santa Fe, and the Burlington Railroads. These tests included not only measurements of lateral acceleration and car body roll on many curves and many miles of track under operating speeds, but also included static lean measurements of the car to determine data on the relationship between car body roll and unbalanced elevation. From a comprehensive study and analysis of these data as presented in the accompanying report the following conclusions and recommendations have been formulated:

Permissible Speed on Curves

The present practice of calculating the track inclination angle by dividing the elevation by the track gage, 56½ in, should be revised to obtain this angle by dividing the elevation by 60 in. This length, 60 in, approximates more closely the distance between bearing points on the rail of the track level which is used by the track man in placing the elevation in curved track. Using this distance gives the following formula for determining the equilibrium speed for any given conditions of elevation E_R, speed V_e, and curvature D.

$$E_R = 0.00070\ V_e^2 D$$

The tests have indicated that for types of modern equipment having soft springs and no provision for restricting the roll of the car body on curves the present AREA limitation of 3-in unbalance should be continued. Upon this basis the permissible speed on a curve is equal to the calculated equilibrium speed for the actual elevation of the curve plus 3 in.

For cars having stiffer springs, outside swing hangers (and springs) or roll stabilizers reducing the amount of roll with unbalanced elevation, the tests have shown that a permissible unbalance on curves of over 4 in can be tolerated by the more favorable types of equipment. A formula is given for determining the amount of this permissible unbalance related to the actual roll characteristics of the equipment in question based upon data obtained from static lean tests. These conclusions are with respect to the amount of steady lateral acceleration that is comfortable.

Transition Curves

A new and different procedure is recommended for determining the length of transition curves, based on the rate of change of lateral acceleration entering and leaving the curve rather than on the rate of change of elevation. The formula recommended, $L_{min} = 4.88\ V$, is based on the fact that a constant period of time, 3.3 sec, must be used to attain a given acceleration if the transition period is to be comfortable. This reasoning indicates that revision of AREA practices is desirable in some cases, particularly in light curves with small elevations. Over the usual range of conditions, results are similar to the AREA recommendation.

The practice of placing part of the elevation on tangent on curves where the spiral is very short or where there is no spiral, was found to give a very disagreeable jerk, the passenger being thrown first one way and then the other at the entrance and exit of the curve. It is preferable to provide all of the elevation within the spiral, and to have a spiral for this purpose, even though it be short.

Clearance

With respect to clearance the test data gives displacement characteristics due to roll of the car body on the springs of the various types of passenger cars included in the tests as related to the unbalanced elevation. A method for determining the angle of lean from static measurements of any particular type of car is also explained. The records indicated that an allowance of ± 1 deg in car body roll will provide for irregularities in line and surface for representative main-line track for speeds up to 90 mph.

B. INTRODUCTION

1. Acknowledgement

The research program reported in the following was initiated at the instance of AREA Committee 5—Track, to obtain information needed for its assignment "Critical Review of the Subject of Speed on Curves as Affected by Present Day Equipment." Inasmuch as the study also involved the characteristics of the equipment the work was carried out as a part of the research program of the Joint Committee on Relation Between Track and Equipment of the Engineering and Mechanical Divisions of the Association of American Railroads under Assignment 7—Relation of Degree of Track Curvature, Speed, Elevation and Equipment Design to Passenger Riding Comfort. Shortly after the work was underway, AREA Committee 28—Clearances, requested research assistance in connection with its assignment "Clearance Allowance to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear and Spring Deflec-

tion, Collaborating with the Mechanical Division, AAR." It was possible to expand the plan of the test so that the data needed by Committee 28 could be obtained.

The tests were made and the following report was prepared under the general direction of G. M. Magee, director of engineering research, and W. M. Keller, director of mechanical research. The tests were under the direct charge of Randon Ferguson, electrical engineer, assisted by M. F. Smucker, assistant electrical engineer. Mr. Ferguson prepared the report. J. G. Britton, engineering assistant of the Mechanical Division, assisted in the tests and the preparation of the report.

Tests were made on eight railroads, all of which furnished without charge the cars requested and placed them in trains for the test runs. One railroad, the Chicago, Milwaukee, St. Paul and Pacific, also furnished a diesel locomotive for special runs. The railroads are the Louisville & Nashville; Kansas City Southern; Chicago, Burlington & Quincy; Delaware, Lackawanna and Western; New York, New Haven & Hartford; Chicago, Milwaukee, St. Paul & Pacific; Pennsylvania; and the Atchison, Topeka & Santa Fe. The test on the L&N was made with the Chesapeake & Ohio track inspection car, and facilities and aid in installing the AAR equipment were furnished by the C&O.

Supervisory and shop personnel of all the railroads gave very effective and enthusiastic assistance in preparing for and running the tests.

Helpful advice and technical suggestions were obtained from various people interested and conversant with such matters. These included H. K. Harwick, W. W. Seary and Michel Watter of the Budd Company; R. N. Janeway of the Chrysler Corporation; Sergei Guins and J. A. Kell of the C&O; and D. R. Whitehead and others of the Eclipse Pioneer Division of Bendix Company. S. M. Dahl of the CMStP&P, chairman of Subcommittee 5 of Committee 28—Clearances, has taken an active personal part in the tests on matters pertaining to clearances and has contributed much to the method of testing and analysis of the results.

2. Purposes of the tests

The present speed limitations on curved track as given in the AREA Manual are calculated on the basis that the maximum comfortable speed on a curve is a speed that would require 3 in additional elevation on the outer rail to obtain an equilibrium condition (equal loads on the inner and outer rail and the resultant of the centrifugal and gravity forces on the car body and passengers normal to the plane of the track). This criterion of 3-in unbalanced elevation is applied to all degrees of curvature, amounts of elevation in the track and lengths of spiral.

This basis was established in 1914 by a special committee of the AREA from a theoretical analysis of the factors involved and the personal observation and practical experience of the committee members. Introduction of diesel power with higher operating train speeds and passenger cars of greatly changed body and truck designs, including much more flexible springs, snubbers, and stabilizers, made it desirable to review the present practices in regard to speed limitations in relation to the track and modern passenger equipment. The electrical instrumentation now available makes it practicable to measure quantitatively the various factors involved for analyzing the problems in a logical manner.

The design of transition curves was not mentioned specifically in the assignment for investigation, but since these curves have such an important part in the ride comfort on a curve, the data available were analyzed to give such information as possible on this phase of the problem.

The test program was planned to include types of equipment representative of those in general use on the various railroads of the country, each car tested having features characteristic of the practice of the railroad or manufacturer. The number of railroads involved assured the inclusion of a full range of variation in track design and standard of maintenance.

No published data were found giving the effect on persons of a constant steady acceleration of the type, range and manner of application encountered in traversing a circular curve. It was thus considered necessary to run tests to establish a basic relation between comfort and a measurable physical quantity, such as acceleration.

Since the dynamic measurements of the lean of the car body have direct bearing on the clearance required, these data are analyzed in the report to give information in this regard for the previously mentioned assignment of Committee 28—Clearances. Special tests were also made for Committee 28 in which the static lean and lateral movements of the cars at various inclinations were measured for correlation with the dynamic measurements.

Several types of cars originally included in the program were not tested because later experience showed them to be impractical or of doubtful value. The objectives of the program may be stated briefly as follows:

a. Establish the basic relation between ride comfort on a curve and lateral acceleration due to unbalanced centrifugal force.

b. Determine the suitability of the present speed limitation practices with respect to the equipment in present use.

c. Evaluate present track practices with regard to elevation, transition curves, and variability of line and surface in relation to modern passenger cars.

d. Determine the effect of modern passenger car design on clearance rquirements.

e. Recommend any changes in practice or design that appear beneficial and practicable.

3. Test Program

The tests were made on eight railroads. Mechanical data on the cars are given in Table 1. The several railroads and the salient characteristics of the cars are as follows:

Louisville & Nashville

The Chesapeake & Ohio track inspection car was used as an instrument car, and observers recorded their impressions of the ride as each curve was traversed. This car is of a special design and not representative of any general type. The test was a preliminary run to see if it was feasible to get a basic correlation between the sensations of the observers and the instrumental readings and not to test the car. At this time instrumentation had not been developed to measure the car body angle, but the test results indicated this was an important factor. Work was shortly started to develop a portable instrument suitable for continuously indicating the angle of the car body with respect to the vertical.

Kansas City Southern

An early design of the modern-type car was used for another test using observers for a check on the correlation of ride comfort with instrumental readings found in the preliminary test. The instrumentation of this test included a newly developed portable gyroscope adapted for measurement of inclination of the car body. A wide variety of curves were tested, some at speeds considerably in excess of the 3-in unbalance speed. A lean test was made later on this some coach.

Delaware, Lackawanna & Western

Tests were made on two coaches of similar design except that one had inboard swing hangers and the other outboard hangers.

Many curves were passed on the round trips between Hoboken, N. J., and Buffalo, N. Y., but most of the speeds were under the 3-in unbalance limit. Lean tests were later made on both coaches.

New York, New Haven & Hartford

A modern outboard swing-hanger coach and an older type coach with leaf springs were tested on round trips between Boston, Mass., and New York. A lean test was later made on the new coach. Numerous curves up to about 10 deg were tested.

Chicago, Burlington & Quincy

A dome car with a roll stabilizer was tested in a round trip between Chicago and Minneapolis, Minn. A lean test was made later on the same car. The curves were not sharp, but the speeds were in general high.

Atchison, Topeka & Santa Fe

A modern Pullman car was tested with a roll stabilizer and then the anti-roll devices were removed. Round trip runs were made between Chicago and Kansas City, Mo. The same car was later lean tested without the roll stabilizer. The curves were of moderate sharpness and speeds moderate. A lean test was also made recently on a similar car with a roll stabilizer. This car was a coach.

Chicago, Milwaukee, St. Paul & Pacific

The standard design coach of the railroad was tested in a round trip between Chicago and Minneapolis and on special high-speed runs between Milwaukee and Watertown, Wis. This coach has a truck of markedly different design, having large diameter coil springs placed outside the frame, giving a broad base of support (spring and side-bearing centers, 96.0 in) for the car body, and uses no swing hangers as in the conventional type truck. The curves were mostly under 3 deg, but the speeds were fairly high on the run in regular service, and in the special runs were high enough to give indication of the result of exceeding the 3-in limitation by a considerable amount. A lean test was made at the time of the special running tests.

Pennsylvania

A late model car and truck using a leaf spring for damping action in combination with coil springs was tested in a round trip between Pittsburgh, Pa., and New York over a large assortment of curves at fairly high speeds. A lean test was made before the running tests.

The tests represent a wide variety of types of equipment and track. Complete data are not available on the track of all the roads, as records are not kept of some features, such as length of spiral, and some of the scatter found in the plotted points may be a result of discrepancies between the actual elevations and curvatures and the nominal values on the track charts.

C. TEST INSTRUMENTATION AND PROCEDURE

1. Ride Comfort Test

The preliminary test made on the L&N indicated that good correlation was possible between the sensations governing ride comfort and the lateral acceleration upon the passenger, and that it would be sufficiently accurate to use instrumental measurements for future tests. However, the discrepancy between the measured and the equivalent calculated acceleration was so large that it was evident that some other factor was present in this test that needed consideration. This factor was found to be the roll of the car body with reference to the trucks due to the action of the swing hangers and truck springs under the lateral force in going around the curve. This car had relatively stiff springs, and since the newer cars could be expected to be more susceptible to such action, it was evidently necessary to measure the amount of this lean. The test program was set up to include a relatively large number of cars, so it was at once apparent that in order to keep the costs and time within practicable limits all test equipment had to be relatively portable, easily installed and usable in regular revenue movements.

With the above requirements in mind a study was made of instrumentation that could be built or adapted to the purpose. A vacuum-tube type accelerometer with high level output was found suitable to drive directly an indicating meter with portable battery power. Such an instrument was built on special order by the company making the accelerometer. It was also found capable of driving a recording milliammeter by using a small direct-coupled amplifier built by the laboratory staff. The amplifier was also battery powered. The recording milliammeter had a full swing period of about ½ sec. The partial amplitudes of the records have a correspondingly shorter response time. This relatively slow response helped damp some of the higher frequency variations due to oscillation of the truck and variations of the track and made it easier to read the average lateral acceleration produced by the track curvature. In some tests the lateral acceleration was measured by a resistance-type accelerometer and an amplifier and recording oscillograph with high-frequency response as a check on the correctness of the other recorder.

The axis of the lateral accelerometer was placed parallel to the car floor and transversely of the longitudinal axis of the car. In the tests where the check recording was made on the lateral acceleration, the accelerometer was mounted on a steel block weighing about 25 lb, which was placed on the car floor. An accelerometer placed to indicate vertical acceleration was also applied to the same steel block to give information on the vertical ride on the L&N test. The higher response equipment picked up high-frequency vibrations not important to the purposes of the tests, so it was found helpful to eliminate these by applying damping to the galvanometer circuit that had a sharp cut off at 10 cps. Vibrations higher than this may be annoying if sufficiently large but are generally not important in passenger car ride comfort. Since the acceleration varies in amount as the square of the frequency (amplitude constant), the higher frequency vibrations tend to overshadow the lower frequency effects, which are relatively more effective on persons, and make the record difficult to interpret.

A view of the "ride meter" instrument and recorders are shown in Fig. 1, and of the higher response instrumentation in Fig. 2.

It was highly desirable that instrumentation for the measurement of the angular position of the car body be readily portable and easily installed. This requirement prompted consideration of a gryoscopic instrument, and consultation with engineers at the Eclipse Pioneer Company, indicated a portable-type gyroscope, such as used in aircraft control, would have sufficient accuracy, and the inclination would appear as an electrical output that could be recorded by making some modifications in the gyro. Since no new equipment was available at that time, a surplus unit was obtained at a very reasonable cost and adapted to the test needs. The results have been quite satisfactory.

The gyroscope is kept erect by pendulums and integrating amplifiers that apply a torque to the gyro for erection when the average signal from the pendulums say it is needed. When traversing a curve an acceleration besides that of gravity is applied to the pendulums which causes them to give an incorrect indication to the gyro and make it tend to assume a position off the vertical. This error was minimized in this case by making the erection rate quite slow—3 min per deg. The time required to go around most curves is, of course, much less than 3 min, and the error from this cause may be expected to be a small part of a degree. The gyro required 400-cycle, 3-phase power, and this was obtained from a small rotary inverter. The inverter was run from 32-v direct current which could be obtained from the car battery, or in case of necessity a set of small storage batteries (also war surplus) would run it for 4 hr. A view of the gyro is shown in Fig. 3.

A speedometer was applied to the axle of the cars, or the output of one of the generators on the anti-slide control was used to indicate speed of the train. The whole group of instruments was set up between two pairs of seats facing each other, using a portable table built for the purpose. Part of the equipment in place may be seen in Figs. 1 and 2. A push-button switch was operated at mile posts and other locations, producing marker indications on all recorders. The proper designation was then stamped or written on the record.

On the tests in which a group of observers was needed, representatives of railway engineering and mechanical departments and railway equipment manufacturers indicated their willingness to participate as observers. Sections of track with considerable curvature were selected and each curve given a designation. These designations and the mile posts were listed in tables given to each observer. As the curve was traversed its designation was called out, and each observer put a check mark in the column of his table that best described the ride. Four degrees of sensation were used—not perceptible, perceptible, strongly noticeable and uncomfortable. The correlation of the observations was found quite good with respect to acceleration, and the correlated results were used in the later tests for determination of the "Ride Index" from instrumental readings of lateral acceleration.

The speed at each curve was written on the records, and the mile post number and other designations were noted at the marker indications on the record.

2. Lean Test

The lean test equipment was relatively simple, consisting of special scales with level bubbles, a plumb bob, 50-ft tape and other scales. The measurements were taken in such manner as to give the total lateral movement due to play and swing hanger movement as well as the inclination of the car body.

The first lean tests were made on actual curves with the required elevation, but the difficulty of handling the cars and finding the proper elevations in a reasonable distance prompted the consideration of an easier method. A suggestion by Mr. Cartwright of the New Haven and chairman of the Joint Committee to run one side of the car up on oak shims as they had done in a previous test was found to be quite satisfactory, and subsequent tests were done in that manner in a car shop where the floor was at the level of the top of the rail. Winches in the car shop were used to move the car on and off the oak shims. A view of a lean test is shown in Fig. 4.

Lean tests have been made on all cars tested except the older type car on the New Haven and the C&O track inspection car used on the L&N.

Measurements in the lean tests were first taken while the car was on level track. After these basic values were measured, the car was elevated on one side, and all measurements changed by the inclination were repeated. The car was elevated to 3 heights, usually, 2, 4 and 6 in. A diagram showing the measurements taken is in Fig. 41.

On some cars measurements were taken of the equalizer spring deflection and expansion, bolster spring deflection and expansion, lateral movement of the bolster, and car body displacement at mid-length of car to give additional information and to aid in clearance calculations.

From the measurements taken the displacement due to lateral play in the truck and the displacement due to the car tilting on the springs can be calculated. These measurements and the values of displacement thus calculated are given in Sec. F of this report.

D. RIDING COMFORT ON CIRCULAR CURVES

1. Analytical Considerations

a. *Elevation of Outer Rail on Circular Curves*

The AREA Manual[1] states that safety and comfort limit the speed on curves and that experience has shown that safety and comfort may be maintained if the speed is limited to a value such that 3 in more elevation is required to give an equilibrium condition (equal loads on the inner and outer rails and the centrifugal force on the car body and passenger balanced by the elevation of the track). The formula given in the Manual for the equilibrium condition is

$$E_R = 0.00066\, V_e^2 D \qquad (1)$$

where E_R is the required elevation for equilibrium in inches, V_e the equilibrium speed in miles per hour, and D the curvature in degrees.

The numerical coefficient in this equation is based on the angle of inclination being determined by the elevation of the outer rail and the track gage of 56½ in. Some discussion has developed concerning the accuracy of the coefficient in this formula. The distance between the bearing points on the rail of the track level which is used by track men in placing elevation in the track on the rails is actually closer to 60 in instead of 56½ in, so this value of 60 in gives a more precise evaluation of the track inclination angle. Use of 60 in. in calculating the above formula would give

$$E_R = 0.00070 V_e^2 D \qquad (2)$$

In Fig. 5 are plotted curves for finding the elevation required for balanced conditions for curves of 1 deg to 10 deg for various speeds, using Eq. 2. Given the speed, curvature and elevation, the unbalanced elevation can be obtained by taking the difference between the elevation required and that used. The use of the modified formula was found to give considerably better correlation in the plottings involving the calculated unbalanced elevation. That is,

$$E_U = E_R - E_A \qquad (3)$$

where E_U is the unbalanced elevation and E_A the actual track elevation.

This unbalanced elevation can be related to the acceleration and force on the car and objects in the car.

The centrifugal force, *F*, on a body traveling a curved path is

[1] All references are presented on page 163.

$$F = \frac{WV^2}{gr} \tag{4}$$

where

W is the weight of the body,

g the acceleration of gravity,

V the speed,

r the radius of the curve.

Referring to the diagram (Fig. 6), it is seen that in the case of a car going around a circular curve at the equilibrium speed

$$R \sin \propto = \frac{WV_e^2}{gr} \text{ and } R \cos \propto = W$$

where $\propto$ is the angle of the plane of the track.

Then

$$\frac{R \sin \propto}{R \cos \propto} = \tan \propto = \frac{WV_e^2}{gr} \times \frac{1}{W} = \frac{V_e^2}{gr}$$

and also

$$\sin \propto = \frac{E_R}{G}$$

where G is the effective gage of the track (60 in) and E_R the elevation required for an equilibrium condition.

Since there is a negligible difference between the values of the sine and tangent for small angles such as the track inclination we can equate the two with reasonable accuracy, thus

$$E_R = \frac{V_e^2 G}{gr} \tag{5}$$

It will be most convenient to express E_R and G in inches, V_e in miles per hour, and the curvature, represented by the radius r, in degrees.

$$r = \frac{5730}{D} \quad (r \text{ in feet, } D \text{ in degrees})$$

If G is taken as 60 in

$$E_R = \left(\frac{V_e \times 5280}{3600}\right)^2 \times \frac{60}{32.16} \times \frac{D}{5730}$$

$$E_R = 0.00070\, V_e^2 D \tag{2}$$

E_R is the required elevation for an equilibrium condition.

The component of the weight, W, in the plane of the track is

$$H = W \sin \propto = \frac{WE_A}{60} \tag{6}$$

The force H acts in opposition to the centrifugal force F, and the unbalanced force F_u is approximately*

* The component of F_u in the plane of the inclined track is proportional to cos $\propto$, which for an angle of 6 deg is 0.995.

$$F_u = F - H = \frac{WV_e^2}{gr} - W\frac{E_A}{60}$$

or

$$F_u = \frac{W}{60}\left(\frac{V_e^2 \times 60}{gr} - E_A\right)$$

Substituting E_R

$$F_u = \frac{W}{60}(E_R - E_A) = \frac{W}{60}E_u \quad (7)$$

The equation above applies either to the weight of the car or an object within the car, and further

$$F_u = Ma = \frac{W}{g}a$$

where M is the mass of the object and a is the lateral acceleration due to the unbalanced resultant of F and H

Then

$$F_u = \frac{W}{g}a = \frac{W}{60}E_u$$

and

$$a = 0.0167\ E_u \text{ (in terms of } g) \quad (8)$$

For example, if $E_u = 3$ in, $a = 3 \times 0.0167 = 0.05\ g$

If a person weighing 150 lb is subjected to this acceleration the force is

$$F_u = Ma = \frac{150}{g} \times 0.05g = 7.5 \text{ lb}$$

The active axes of the lateral accelerometers were placed parallel to the car floor and transversely to the length of the car to measure the lateral acceleration. The accelerometer was generally at approximately the height of a sitting person. However, the height is not of great importance for the passenger, as the only other acceleration likely to be present in that direction which would be affected by the height of the accelerometer is that due to the car body roll, and this will generally be of relatively small magnitude because the large mass of the body and the spring coupling between it and the trucks limits the velocity of the roll to a small value.

b. *Effect of Lateral Acceleration on Ride Comfort on Circular Curves*

The ride comfort problem is very complex. There are many factors and variables, and if all of them are taken into account experimentally the tests required would be very long and expensive. Much work has been done in this field by various experimenters. The most extensive tests and consistent data were those published by F. J. Meister[2]. This work and a resumé by R. N. Janeway[3] were used as a basis for analyzing the riding of a test car with various amounts of wheel unbalance.[4] In this last named work the results were simplified and used in such manner that the criterion would always be on the safe side no matter what the attitude of the passenger, the direction of the acceleration or the disposition of the several acceleration components.

The human body is a complicated structure and has been found to be more sensitive to certain frequencies and directions of acceleration than to others. Since all the reported tests on persons had a lower frequency limit of approximately 1 cps, it was thought best to make observer tests more closely representative of our conditions on curved track. Work done by some investigators on low-frequency acceleration with respect to elevators placed the person in a standing position where he can resist the vertical acceleration more readily, and that for aircraft covered a much higher range of acceleration than encountered in railroad passenger cars.

Acceleration, or some quantity directly related to it, has been found in the above mentioned experimental work to be a good measure of ride comfort and was selected for the tests to determine its suitability for use as a criterion of the ride comfort on a curve. It should be borne in mind that the passenger is ordinarily sitting in a seat, and as the curve is traversed is subjected to a uniformly changing acceleration which reaches a maximum at the end of the transition spiral and remains constant laterally with respect to the passenger as long as the circular curvature is constant. If the curve is a half mile in length this constant acceleration may be a matter of 30 sec or some similar period of time. Since it is easy to become confused in thinking about velocity and acceleration and their relations, the diagrams in Fig. 7 are given to show graphically some of the relations present with respect to the lateral acceleration on the car due to centrifugal force and the vertical quantities affected by the elevation of the outer rail. In Fig. 7–a it can be seen that the lateral acceleration is increasing uniformly in the spiral until the circular curve is reached and then remains constant to the runoff spiral, where it decreases in the same manner. Under certain conditions of frequency or direction of application the rate of change of acceleration has been found to be the best criterion of comfort rather than the maximum acceleration. This point will be discussed later in connection with the basis for the length of spirals required.

As stated previously a preliminary test was run to check instrumentation and determine whether a basic correlation could be obtained using acceleration as the criterion of ride comfort. When this preliminary test showed the idea to be sound a more extensive test with additional instrumentation and a more representative car was made. The results of both tests showed such similarity in the correlation between observer reaction and measured lateral acceleration that the data were combined and plotted in Fig. 8 as a "Master Curve" for relating the instrumental readings to passenger comfort for the other tests without the use of a group of observers. All points are not plotted since many coincided with each other, and the points shown are the average of all the points for a particular degree of curve and acceleration. Each point thus represents the collective opinion of at least 20 or 30 observers concerning one curve and may be the average for several curves. On the two railroads data were obtained on over 300 curves in the test stretches selected. A curve in Fig. 8 has been drawn to represent the average distribution of the plotted points, and it is this curve which has been used for the subsequent tests to evaluate the "Ride Index" without the use of observers from the measurement of the lateral acceleration.

Numerical values have been assigned arbitrarily to the several zones of sensation as was done in the previously mentioned tests[4] concerning unbalance in car wheels and other factors. The four zones of sensation chosen, as shown in Fig. 8 are "Not Perceptible", with a numerical value from 0.0 to 1.0; "Perceptible", between 1.0 and 2.0; "Strongly Noticeable" between 2.0 and 3.0; and "Uncomfortable", from 3.0 to 4.0. This assignment of numerical values permitted a weighted average to be obtained that represented the conclusions of all the observers by one number. To illustrate, assume 8 observers were of the opinion that the acceleration was perceptible. The middle of the perceptible band is 1.5 and the product, $8 \times 1.5 = 12.0$, represents the summation of the opinions of this group. If 12 thought the ride on the same curve strongly noticeable, the product for this group is $12 \times 2.5 = 30.0$. The sum of the two group products is 42, and the average for the whole 20 observers of both groups is $\frac{42.0}{20} = 2.1$, which is just beyond the threshold of the Strongly Noticeable zone. If the observers represent a range of physical characteristics, this average figure tends to represent the average opinion of such a group of miscellaneous physical make-ups.

The observers were requested to disregard acceleration that appeared to be due to track irregularities or oscillations of the trucks and the entrance and exit parts of the curve and to base their judgement solely on the steady centrifugal acceleration in passing the circular part of the curve.

In the previous discussion it was shown that the acceleration could be expressed in terms of the equivalent unbalanced elevation

$$a = 0.0167\, E_u \text{ (in terms of } g\text{)} \qquad (8)$$

For a 3-in unbalanced elevation, $a = 0.05g$.

This equivalent scale has been placed at the top of Fig. 8, and it may be noted that the average line for the points indicates that 3-in unbalance or $0.05g$ is just within the perceptible zone. If the actual unbalanced elevation for the points in this region were calculated from the speed, curvature and elevation, it would be much less than 3 in, possibly about 1½ in. This will be shown more definitely in other diagrams. The equivalent unbalanced elevation should not be confused with the calculated unbalanced elevation which is given by Eq. (3), and depends on the speed, elevation and degree of curvature and does not take into account the car body roll. As stated previously, the average curve drawn through the points in Fig. 8 will be used in the other tests to interpret the acceleration values into terms of ride comfort.

c. *Lean of Passenger Car Body on a Curve*

A passenger car traversing a curve will tilt and assume a position dependent on the elevation of the track, the speed, the centrifugal force acting on the car, and the mechanical characteristics of the car. If the car is at the equilibrium speed for the curve as determined for Eq. (2) previously given, the car body will have the same inclination as the track. For the car to assume this position on the curve it is necessary that the car body tilt through an angle from the vertical equal to the angle of the inclined track. The track angle and the car angle would in this case be equal, and the difference between the two (the roll angle) would be zero, and the car body would be normal to the plane of the track. This condition is shown in Fig. 9–b.

The car body assumes a different position when the speed of the car is greater than the equilibrium speed. In this case the elevation will not be completely effective in balancing out the centrifugal force created by the circular motion of the car. With this unbalanced force acting at the center of gravity of the car body, it will be displaced outwardly and will tilt on the springs and swing hangers outwardly of the curve. Under normal conditions when the car is above the equilibrium speed, the car body will not incline from the vertical at an angle as great as the track angle. The difference between the track angle and the car angle (the roll angle) will in this case be positive. This condition is shown diagrammatically in Fig. 9–c.

When the car speed is below equilibrium speed the component of the weight of the car in the plane of the inclined track is greater than the centrifugal force acting on the car. This unbalanced force, now acting in the direction toward the center of curvature of the track, causes the car to be displaced inwardly and also causes the car to tilt on the springs and swing hangers toward the inside of the curve. In this case the car will incline from the vertical at an angle greater than the track angle, making the difference between the track angle and the car angle a negative value of roll angle. This condition is shown in Fig. 9–a.

The portable gyro equipment recorded the position of the car body with respect to the actual vertical for all curves tested, and the elevations listed in the track charts permitted calculation of the angle of the inclined track. The value of the track angle minus the car angle can thus be determined for all curves tested. This information makes it possible to determine the attitude of the car body on the curves and also to calculate the displacement caused by the car rolling on the springs (car body roll). This displacement due to roll obtained from the riding tests added to the lateral play displacement can be compared with the values of displacement obtained from the static lean tests.

2. Test Results

a. *The Cars*

The cars selected for tests were each representative of some practice or distinctive mechanical feature considered of sufficient importance to merit a part in the test program. It was considered not feasible or necessary to make tests of all details and variations of the numerous practices and designs in modern car construction. The features selected were also those which were considered most likely to be important in the action of the cars on curved track. The influence of these features on the action of the cars on tangent track is not taken up here and is in itself a complex and highly controversial subject partly because of the difficulty in getting similar results with supposedly identical test conditions.

The mechanical features of the cars considered of importance to this problem are listed in Table 1. It is not considered necessary to give detailed plans of the trucks, but views of the trucks on each the cars are given in Figs. 10, 11 and 12. A study of Table 1 will show the noteworthy features for the several cars, which will be discussed later in their relation to the test results. The spring rates given are a summation of all springs for one side of one truck for the bolster and for the equalizer and represent the comparative effective stiffness at the given position.

b. *The Data*

The test data taken on the ride tests always included three things, though sometimes additional equipment was used to measure other quantities or as a check on the equipment normally used. The lateral acceleration at the middle of the length of the car, the inclination of the car from the vertical, and the speed were the values obtained for each curve. These data, together with the information supplied with regard to the track, were used to calculate other values. The lateral acceleration, by use of the "Master Curve" (see Fig. 8) as previously explained, gave a value to the Ride Index; the angle of the car body with the vertical was subtracted from the angle of inclination of the track, giving the car body roll; and the unbalanced elevation was calculated from the track elevation, curvature and speed. These various quantities and their relation to each other were used to determine the effects of the various car and truck characteristics. The data when plotted generally showed less scatter than would be expected. Some of this scatter is attributed to inaccuracies in the information on the track plans in regard to curvature and elevation. Inequalities of line and elevation in the curves and oscillations of the car will also cause scatter. The practice of the different railroads in keeping the track plans up to date has been found to vary considerably. Some of the points lying considerably off the average variation are undoubtedly due to changes having been made in the track and not yet noted on the plan. However, in most cases there is either a definite trend or a good correlation. Where necessary the points have been averaged for incremental distances and the curve drawn with reference to the average points.

In picking off the values from the records the practice was followed of taking the maximum mean value of the lateral acceleration reached in going around the curve and reading the car body angle at the same point on the reasoning that the best correlation could be obtained in that way, and the roll would be a maximum when the acceleration is greatest. The mean or average value of the acceleration was taken to eliminate the effect of truck oscillations or local irregularities in the track which sometimes appeared in the records at the higher speeds. Views of typical records are shown in Fig. 13. The records in Fig. 13 are accurate tracings of the lateral acceleration and car body inclination as recorded on the Esterline Angus recorder for a typical curve. The speed is quite high, 94 mph, and there is some lateral oscillation in the acceleration record, but it should be noted that the car body is massive enough that these variations are not reflected in the variation of the car body angle. The practice in reading the records was to take the lateral acceleration reading at a maximum point and at the average level of the oscillations. The car angle was then read at the same point, which was generally the minimum car angle or maximum roll angle.

c. *Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation*

Values of the measured lateral acceleration are plotted in Figs. 15 to 26, incl., with reference to calculated unbalanced elevation for the cars tested. As previously shown the lateral acceleration is a measure of the degree of comfort for the passenger, and its amount is influenced by the roll of the car. The calculated unbalanced elevation is a quantity presently used to determine maximum speed restrictions on curves. Obviously then, the relation between these two quantities will tend to indicate something about the suitability of the speed restrictions. Straight lines have been drawn through the general trend of the points, or with reference to average points for incremental portions of the range. The slope of these average lines is an indication of the "comfort" ability of the car to go around curves. This slope is evaluated in Table 2 by listing in the third column the amount of unbalanced elevation at an acceleration of 0.10*g* as picked off of the average lines for the various cars tested. This acceleration of 0.10*g* will be used later as an acceptable upper limit of lateral acceleration. The greater the amount of unbalanced elevation that can be obtained with a given amount of acceleration, the better the "comfort" ability of the car to go around the curve without introducing passenger discomfort.

The value of the calculated unbalance shown in the table for 0.10*g* ranges from 2.80 to 4.40 in. There is 1.60 in difference between the two values, which indicates that 1½ in greater unbalanced elevation can be used with the same degree of comfort for one car than for the other. It may also be noted that the highest values are for cars with outboard swing hangers or stiffer springs or roll stabilizers. The modification of the Santa Fe car to remove the roll stabilizers greatly reduced the ability of the car to get around the curves comfortably, as indicated by the reduction of the unbalanced elevation from 4.20 in to 3.00 in. The roll stabilizer was standard on the Santa Fe equipment. It should also be pointed out that the CB&Q car with almost the highest value is a dome car with a roll stabilizer.

The term "Ride Index" has previously been defined and described, and its correlation with lateral acceleration shown by the test results on 2 railroads for several hundred curves and more than 40 observers. On railroads other than the L&N and KCS where the Ride Index was established by direct observation it was obtained by use of the Master Curve and the measured lateral acceleration. The relation between the lateral accelerations and the Ride Index for the various cars is shown by placing the corresponding Ride Index scale at the top of Figs. 15 to 26, incl. This Ride Index scale can be used to pick off the index values for a 3-in unbalanced elevation as another basis of comparison of the cars. These values are given in the Col. 4 of Table 2. The lower the value of the Ride Index the better the ability of the car to get around the curve with comfort.

Comparison of the values in Cols. 3 and 4 of the table indicate similar effects of the various mechanical characteristics for either criterion, including the two tests where the Ride Index and acceleration were determined independently. The KCS car which had no roll stabilizer and considerable lean showed the next to lowest value of unbalanced elevation, 2.90 for a 0.10*g* acceleration, and next to the highest Ride Index, 1.85 for a 3-in unbalance, both values indicating a lesser ability to go around curves with the usual amount of comfort. On the other hand the New Haven cars showed good values by both comparisons. The outboard swing hanger truck is a relatively new type, and the car body roll has been controlled by the outboard swing hangers and the wider spring base. The other New Haven car was an older type that restrained the roll by considerably stiffer leaf springs (see Table 1), but for this reason was not so comfortable for vertical ride. The same statements apply to the C&O car used on the L&N, which was an old style Pullman type with six-wheel trucks that had been fitted up with various types of track inspection equipment, including a wheel in an engine trailer-type frame at the mid-length of the car for the measurement of curvature of the track.

The CB&Q dome car also showed similarly good ability to go around curves with comfort. This is attributed to the roll stabilizers. It had a 4.30 unbalanced elevation at 0.10*g* and a Ride Index of only 1.40 for 3 in unbalance.

The two cars tested on the DL&W were similar in general design except that one had outboard swing hangers and the other inboard hangers. The values for the two methods of comparison indicate very good ability to negotiate the curves, but there is little difference between the two cars in this respect. The values of the unbalanced elevation for 0.10*g* are 4.00 in and 4.40 in. An inspection of Table 1 giving various mechanical characteristics of the cars shows that the inboard hanger car had higher spring rates for both equalizer and bolster positions. This was accomplished by using two springs at each end of the equalizers (16 per car), and having triple-coil springs in the bolster as compared to double-coil springs in the bolster of the outboard hanger car. This difference in springs compensated to some extent for the effect of the inboard swing hanger in increasing the car body roll in running tests in which both cars gave similar results. The static lean displacement was somewhat greater for the inboard swing hanger, as shown in Col. 7 of Table 2 and in Table 3, possibly due to being free from the restraining action of any adjacent cars.

The Milwaukee car, having a radically different design of truck with large outboard springs but no swing hangers, showed up in the medium or good range, both criterion values being similar for the high-speed tests and in the regular revenue run. The PRR car with inboard swing hangers, which had one-sixth of its weight supported on a leaf spring and the remainder of the weight by helical springs in the bolster, was also in this medium range.

The Santa Fe car was tested with a roll stabilizer and had values in the top range, 4.20 and 1.45. The same car was modified to remove the stabilizer, and the change had a very marked effect on the curve riding qualities, the calculated unbalanced elevation being 3.00 and the Ride Index about the same as the KCS car, 1.80. This car had quite soft springs in both bolster and equalizer and the static lean displacement for 6-in elevation was quite high, 7.33 in (Col. 5, Table 3). With the roll stabilizer in place a test on a similar though somewhat lighter car gave a lean of only 4.37 in. The use of the roll stabilizer is standard practice on the Santa Fe with this class car.

The lateral displacements and displacement due to car body roll (static lean) from the static tests, some of which have been quoted, are given in Table 2 for correlation with the various dynamic values. Most of these lean displacements are in qualitative accord with the dynamic criteria discussed, but there are some quantitative discrepancies which will be discussed more in detail later.

d. *Relation of Car Body Roll to Lateral Acceleration*

The car body assumes a position with respect to the vertical on curved track that is dependent on the elevation of the track, curvature, speed, and the mechanical characteristics of the car. The effect of this car body roll was discussed in detail in Sec. D. The principal effect of the roll is that at speeds greater than the equilibrium speed the direction of the roll is such that the car body becomes more nearly vertical than the inclination the track gives to the trucks, and the effectiveness of the track elevation in reducing the centrifugal force on the passenger is impaired. The greater the angle of car body roll the less the effectiveness of the outer rail elevation in aiding passenger comfort. The car body roll was not measured directly because it was necessary to keep the testing equipment compact, portable, and suited to quick installation for tests in revenue service. The portable gyro gave the angle of the car body with respect to the vertical, and subtraction of this angle from the inclination of the track gave the relative rolling between the track (or trucks) and the car body. This calculation makes it possible to compare all degrees of curvature, elevations and speeds on a common basis for any particular car or test condition. The chief difficulty with this process is that inaccuracy in the information on elevation of the outer rail causes a similar error in the roll angle, and this is undoubtedly the cause of some of the scatter in the plotted points. The roll angles for the various tests are plotted with respect to the recorded lateral acceleration in Figs. 27 to 37, incl. As before, average lines are drawn to indicate the trend of the plotted points.

Use of the above curves gives another criterion of the riding comfort of the car. The car body roll for a 3-in calculated unbalanced elevation was obtained from these curves by determining from Figs. 15 to 26, incl., the lateral acceleration present in each car with a 3-in unbalance and finding the car body roll for the acceleration so obtained from Figs. 27 to 37, incl. These angles have been tabulated in Col. 5 of Table 2. The car body roll as found in the static lean tests interpolated for 3-in elevation has also been tabulated in Col. 6 of the same table. The 3-in static elevation is equivalent to a 3-in unbalance inwardly of the curve. The less the roll angle the better the comfort obtained in going around the curves. It was assumed in the calculations for the roll (and lateral displacement) that the car body rotated about a point at the center plate height.

The dynamic and static values for a given car should be similar, and it is evident from a study of the table that most of them are. However, there were some differences in the test conditions that should be kept in mind. When the cars were tested in running tests they, of course, had other cars ahead and behind them which in most cases had different characteristics than the test car. Also, the static lean test program was a later development, and in most cases the lean test was made after a lapse of considerable time from the running test, so some changes may have taken place in the mechanical condition of the car during the interval.

The roll angles measured dynamically range from about 1.0 deg for the better cars to almost 2.5 deg for those with the greater roll. There is good agreement of some of these roll angles with the static lean test for 3-in elevation, but a few show some discrepancies. The range for the static lean angles is from 0.8 deg to about 3 times that, or 2.5 deg. The maximum difference between the dynamic and static angles is 0.5 deg in the case of the New Haven car with outboard hangers. The static test value of 0.9 deg appears somewhat low on the basis of 3.60 in calculated unbalanced elevation for 0.10g in Col. 3, Table 2. A somewhat similar discrepancy is seen in the Milwaukee test. It should be stated that the Santa Fe car lean tested with roll stabilizer was a coach weighing about 16000 lb less than the Pullman used for the running tests. These values will be later used in illustrating the use of the static lean test in establishing maximum speeds for tolerable comfort for any given type of car.

3. Discussion and Recommendations for Passenger Car Speed Limitations on Circular Curves

The test data on circular curves for the passenger cars of the several railroads and test conditions have been presented in numerous diagrams. In general there has been agreement in results indicated by means of the several methods of comparison, and some of the characteristics have been pointed out and discussed, together with some of the discrepancies and possible explanations therefor. Table 2 lists these various values that were important as criteria of the performance of the cars on curves both for the dynamic tests and the static lean tests.

The test program was planned to include some of the latest type equipment and equipment having features which could be expected to influence the action of the car on curves. It was not practicable to include numerous minor details of equipment design and maintenance and keep the test program within reasonable limits. However, it is believed that the important principles and requirements for best comfort on curves have been established by the results so that improvements in practice and design can be made or the current designs evaluated.

The basic correlation for determining the tolerable acceleration, as shown by Fig. 8, was surprisingly good on two railroads with radically different cars and two different groups of observers. The degree of perception of comfort is not an accurately defined quantity and can be expected to vary among different persons. The selection of a maximum limitation as the acceleration that will be reasonably comfortable is somewhat a matter of judgment, but it would seem logical that the amount noted as Perceptible would be satisfactory as long as the Strongly Noticeable zone was not entered by reason of accidental or random variations. The lower limit of the Strongly Noticeable zone has a Ride Index of 2.00 and acceleration of 0.116g on the average line. There is some scatter of points about the average line, and a zone has been drawn to contain about 80 percent of the points. The upper limit of this zone crosses the Ride Index of 2.00 at 0.10g, which corresponds to an equivalent unbalance of 6.0 in on the basis of acceleration. The use of this upper limit with an acceleration of 0.10g to provide some allowance for variations in elevation, curvature and equipment condition would seem good practice.

As it was not practicable to run the tests with observers in a prone position, it is therefore desirable to determine, if possible, whether any limits set up for sitting will be acceptable to sleeping car passengers, or those standing. The range of the data available from other sources does not permit direct comparison, but does show that sensitivity to acceleration decreases considerably in the very low frequency region. Few tests are available for the correlation of comfort even at a frequency of 1 cps. Meister[2] in his tests at that frequency did not have results for a person sitting. The threshold of the Strongly Noticeable zone at 1 cps in his work for a person standing subject to vertical vibration is 0.075g and for transverse vibration standing is 0.05g. The sensitivity of a prone person to transverse vibration is higher, the same threshold being a little under 0.03g. Tests by Jacklin[10] with transverse acceleration of a seated person also at 1 cps classed as disturbing an acceleration of 0.04g. This threshold is probably a little higher than the AAR Strongly Noticeable threshold. If the same relations are maintained for the still lower frequency or constant acceleration of the ride tests, it would be reasonable to assume that there may be a slightly greater sensitivity to transverse acceleration for a prone person than a seated person. The standing person is also seen to be less sensitive to transverse acceleration, and the limiting condition will thus be for the passengers in the seated or prone position. These results are for steady state vibrations. Irregular or sudden lateral shocks will, of course, disturb the equilibrium of a standing person more than a seated person.

The test data indicated the prime importance of the car body roll in relation to ride comfort on curves and the greater tendency of some cars to roll. The three factors that reduced the tendency to roll were the roll stabilizers, outboard swing hangers and stiffer springs. The use of stiffer springs is, of course, certain to affect quality of vertical ride adversely. The Burlington and Santa Fe cars with roll stabilizers showed up well, and the New Haven car with outboard swing hangers gave similar results. The effect of the outboard hangers on the DL&W car was similar to outboard hanger cars on the other railroads, but on the DL&W car with inboard hangers the roll was restrained by considerably stiffer support, making the action of this car similar to the car with outboard hangers.

Since the car body roll is a primary factor in the ride comfort on curves it is necessary to take this into account in arriving at the permissible speed for comfort. It is assumed that it will not be feasible for most railroads to make running tests and measure the lateral acceleration for this purpose. It has already been established that a lateral acceleration of 0.10g can be tolerated with comfort. This represents an equivalent unbalanced elevation of 6.00 in as given by Eq. 8,

$$a = 0.0167\ E_u g \tag{8}$$

This equivalent to the lateral acceleration in terms of unbalanced elevation will be termed the undiminished maximum of the unbalance that could be used if the car body did not roll and reduce the effectiveness of the track elevation.

Some of the cars tested showed considerably less roll than others under similar conditions. The tests showed that faster scheduled speeds could be made with the cars with the lesser roll, and a similar degree of comfort maintained in the two cases. One road is known to be making such a differentiation between its own equipment and foreign road equipment on the basis of operating experience. This characteristic would seem to be a logical basis for determining speed limits for particular types of equipment where a given train is restricted to one type, or for determining a certain comfortable limit for all cars where several types of cars are operated together.

It has also been found, as will be shown in Sec. F, that the dynamic values of car body roll (displacement) generally have a relation to the unbalanced elevation similar to the static values of unbalance, as shown by the static lean test points lying close to the extension of the average line representing the average relationship of the dynamic variations. However, it should be pointed out that there was some lack of agreement in some cases between the several factors. A suspected source in some cases, especially those involving large amounts of lean, was binding or friction preventing full movement of the car body in the static lean test. Consideration should be given to methods of overcoming this difficulty and making certain the car gets full movement in static lean tests.

As stated above the undiminished equivalent of the unbalanced elevation found permissible on the basis of 0.10*g* lateral acceleration was 6.0 in. This optimum value can be adjusted to allow for the amount of roll by a simple formula. It is evident from Fig. 41 that

$$E = 60 \sin \Theta$$

where Θ is the inclination of the car body due to the roll, E is the equivalent in terms of track elevation, and the effective gage is again taken as 60 in. Then the compensated unbalanced elevation, E_{cu}, which can be used instead of the nominal 3 in without exceeding the 0.10*g* limit of tolerable acceleration is

$$E_{cu} = \left(\frac{6}{3 + 60 \sin \Theta}\right) 3 \qquad (9)$$

The term, 60 sin Θ, represents an unbalanced elevation equivalent to the car body roll which diminishes the optimum amount in proportion to the amount of the roll. The angle Θ in this case is the roll for a 3-in unbalance and may be obtained from a static lean test.

Table 2 shows that the CB&Q dome car with the good performance on the curves had a roll of about 1.4 deg as found from both the dynamic and the static lean tests for 3 in elevation. Substituting this value in the equation for E_{cu}

$$E_{cu} = \left(\frac{6}{3 + 60 \times 0.024}\right) 3 = 4.1 \text{ in}$$

This result checks well with the 4.30 in unbalance for 0.10*g* acceleration and indicates an appreciably greater unbalance can be tolerated with this car than the conventional 3.0 in. The PRR car had an inclination of about 2.0 deg for the same 3 in unbalance, both statically and dynamically.

$$E_{cu} = \left(\frac{6}{3 + 60 \times 0.035}\right) 3 = 3.1 \text{ in}$$

which indicates the present limitation of 3 in unbalance will be comfortable. This value also agrees reasonably well with the 2.80 in unbalance in Col. 3 for 0.10*g* acceleration. The Milwaukee car had a dynamic lean of 1.8 deg for the high-speed dynamic tests and 1.3 for the regular run. The static lean test roll is 1.4 deg. The compensated elevation using the static lean value

$$E_{cu} = \left(\frac{6}{3 + 60 \times 0.024}\right) 3 = 4.1 \text{ in}$$

This value is comparable with 3.20 in or 3.30 in, which is a discrepancy of about 0.8 in. It is evident there is some difference in the static and dynamic action that is not apparent from the information available. Use of the high-speed roll, 1.8 deg, gives a close agreement. The above unbalanced elevations may be applied to the calculation of permissible speeds. The manner of application would be as follows. If the permissible unbalance of 4.1 in applies and the curve has 6 in elevation and curvature of 3 deg, $E_R = 4.1 + 6.00 = 10.1$ in = elevation required for equilibrium.

From Eq. 2, $10.1 = 0.00070\, V_e^2 \times 3.0$

or

$$V_e = \sqrt{\frac{10.1}{0.0021}} = \sqrt{4810} = 69 \text{ mph}$$

The use of a set of curves for E_R such as Fig. 5 will facilitate this calculation for V_e. The speed permitted for the standard 3.0 in unbalance would be in this case

$$V_e = \sqrt{\frac{9.0}{0.0021}} = \sqrt{4280} = 65 \text{ mph}$$

The car with the roll of 2.0 deg would have a limit of

$$V_e = \sqrt{\frac{9.1}{0.0021}} = \sqrt{4330} = 66 \text{ mph}$$

Thus a total difference of 4 mph results between the extremes. The application of the Manual formula with the smaller coefficient and the conventional unbalance of 3 in will give a maximum speed of 67 mph. Thus the modification for some cars suggested is not actually as much of an increase as it first appears.

It is suggested that in cases where it is desired to increase scheduled speed with equipment less subject to roll, that static lean tests be made and the above formula applied.

In making static lean tests with cars having considerable roll it must be determined whether the roll has been stopped by lack of clearance, and it is not considered safe to use one large elevation, such as 6 in. It is later recommended that at least three elevations be used to aid in judging the accuracy of the lean tests values. Some revisions in the methods of making the lean tests should also be tried. Apparently, the failure of the static lean test points to agree with the trend of the dynamic points in some of the diagrams for correlating the two sets of tests given in Sec. F was due to some such cause. Further consideration should also be given to determining the reasons for discrepancies, such as in the case of the Milwaukee car where there was good agreement in the roll angles for the static and dynamic tests, but the lateral acceleration was higher than indicated by the roll angle.

The above discussion indicates the detrimental effect of car roll as far as curves are concerned but must not be taken to mean that the roll must be eliminated. Roll is inherent in the type of support that modern cars have and is a result of the design to meet the need for flexibility on curves and cushioning for lateral and vertical shocks that come from roughness or misalinement in track and oscillations in the equipment. However, if the car body support was a pendulum type and placed near the center of gravity of the car body, the roll would be diminished or possibly be in the opposite direction, and the passenger would be placed in a position more nearly corresponding to the equilibrium condition for standard equipment. This type of design was tried experimentally in the "Hill" car, but according to information supplied the pendulum support had too much stiffness to function completely as intended, and the support design was not practical in the present type car. A new, small size, lightweight design incorporates this method of support, and if its use is found practicable would be a good subject for ride tests for comparisons with standard type equipment. Other somewhat similar designs with low center of gravity and new truck designs would also be of interest.

The use of a pendulum-type support of the car body would improve the curve riding characteristics by reducing the car body roll or even reversing its direction but would probably be feasible only in lighter weight, smaller size cars. A recent article concerning two new light German trains[9] states, "The pendulum spring suspension (in which the car is suspended from above its center of gravity and therefore leans to the inside rather than the outside of the curve) greatly increases the speed at which curves can be taken comfortably, as tilting counteracts the centrifugal force on the passenger instead of adding to it as the conventional suspension does." It is claimed that this train has sufficient buffing resistance and improved impact absorption and economy.

Many of the cars recently built or under construction have outboard swing hangers. It has been the experience of some roads that the outboard hangers are more easily accessible for maintenance and inspection and are a simplification compared to the use of roll stabilizers. Some of the new cars are also using a large diameter center plate which may also help reduce the roll, though one of the advantages stated is the damping out of rotational oscillations (shimmy) of trucks. These new designs can be expected to give improved ride on curved track.

There are, of course, other actions affecting ride comfort on curves to some extent which have been somewhat averaged out in the data as here presented. Some cars will proceed around the curvature more smoothly than others, especially at speeds giving the larger unbalances. Irregularity in the action on both curved and tangent track is also accentuated by wear and play in the truck parts. Design of the swing hangers is known to influence the effect of lateral track irregularities and truck oscillations on riding qualities. The spacing, angularity and length of the hangers are all factors that should be combined in their proper relations to give the best overall condition.

Tests made by Loach and Maycock on the British Railways and recently reported[7] have had some objectives and procedure similar to the tests here discussed. Measurements were made of lateral acceleration and correlated with observer reactions on 14 curves that had been carefully put in line and cross level and on 38 in good condition but not specially prepared.

A more detailed gradation of sensation levels was used than in the AAR tests. Comparison of the two sets of levels is shown in Fig. 38 in what would seem to be an approximate correspondence of the several zones and values of the unbalanced elevation equivalent to the measured acceleration in the two sets of tests given for corresponding values of Ride Index. It is seen that two sets of values of unbalance check closely except for the two highest values. The Ride Index numbers are, of course, not comparable.

Some conclusions from the British tests are that the maximum cant deficiency (unbalanced elevation) shall be 3½ in, which shall be reduced as the cant increases, being given as only 2 in for a 6-in elevation in their "Railway Curves—Rules for Speed of Trains on Curves in Relation to Radius, Cant and Length of Transition." They limit the maximum elevation to 6 in because of danger of derailment. No justification was seen from the AAR tests for reducing the permissible unbalance with the elevation, variability in action being more dependent on speed.

E. TRANSITION SPIRALS

1. Analytical Considerations

One of the recognized requirements for smooth, comfortable riding around curves is a proper transition curve between the tangent track and the circular portion of the curve. The change from no curvature to a given constant curvature must be made gradually at a rate that will not cause a lurch or bump at the entrance and exit of the curve. The usual method is to make the curvature and elevation of the transition curve change uniformly with distance along the curve. No tests were made to determine specifically the observers reactions to the ride around the spiral portions of the curves, but instrumental readings were made through the spirals. The records have been read for those portions, and some discussion of these results and those of other workers may be helpful in establishing some of the basic relations and indicate possible improvements in practice or limiting conditions that may improve riding comfort.

A diagrammatical representation of the relations between deflection, velocity and acceleration is given in Fig. 7 to facilitate their consideration. In Fig. 7 the variation of the lateral acceleration due to the centrifugal force (assuming a speed greater than the equilibrium speed) is shown diagrammatically. Since the centrifugal force is inversely proportional to the radius of the curve and the elevation for a given speed, and they both change at a linear rate, the lateral acceleration increases at a constant rate until the full curvature of the circular portion of the curve is reached, when the acceleration remains constant till the exit spiral is reached. This is a logical method of easement into the curve, and it chiefly remains to determine the length which the spiral shall have.

The formula specified in the AREA Manual[5] for determining the minimum length of the spiral is

$$L_{min} = 1.17\ E_A V \tag{10}$$

where L_{min} is the minimum length of the spiral in feet, E_A the actual elevation of the outer rail in inches, and V the speed in miles per hour.

The formula makes the elevation a fundamental factor in determining the length. A study of Fig. 7 will show that the elevation is only an incidental factor in determining whether the length of spiral will be comfortable, and it would seem more logical to consider directly the factor which governs the comfort in going into a curve. A somewhat similar statement was made by Talbot[6] as follows: "The rate of attaining the superelevation is sometimes given as the governing consideration, but in reality this rate is governed by the speed." The experience of most workers in the field of ride comfort is that the rate of change of the acceleration (lateral in this case) is an indication of the comfort in the lower frequency ranges. The term "Jerk" value has been aptly applied to this quantity and it is expressed mathematically as $\frac{dy^3}{dt^3}$ in g/sec. This quantity has been found to be a better criterion of comfort in the low ranges of frequency than the acceleration. The principal difficulty here is determining if the acceptable ranges of "Jerk" determined by the tests referred to will apply to the type of condition we have here presented, as no observer comments were obtained on the transition curves.

In Fig. 7–b the vertical elevation y is shown diagrammatically along the length of the curve, changing at a uniform rate in the transitions (period t_1) and being constant in the circular part of the curve (period t_2). The vertical velocity (dy/dt) is shown in Fig. 7–c, and it should be noted that theoretically the vertical velocity changes instantly at the point of spiral from zero to some finite constant value which is specified in the AREA Manual[5] as not more than 1¼ in/sec, a relatively low velocity. Of course, there will not actually be a "corner" in the rail as shown in Fig. 7–b, and there will not be an instantaneous change of velocity to a constant value, but at least here is a place where a vertical bump might be expected under some limiting conditions. Reference to Fig. 7–d shows that at this same point of spiral there is theoretically an infinite vertical acceleration because of a change of velocity that occupied an infinitely small length of time after which the acceleration is zero, until the end of the spiral is reached because the vertical velocity is constant, a condition that supports the previous statement that the rate of change of the vertical elevation is only incidental. If there is no vertical acceleration in the spiral no sensation of discomfort is apt to be present. The rate of change of acceleration (Fig. 7–e) is similar in form to that for the acceleration.

The point of spiral and point of curve is thus seen to be a possible source of a vertical bump. Some evidence of this was found in the only test where vertical acceleration was measured, but the data were not conclusive. In the track there is some easement because sharp changes cannot readily be put into the stiff rail and a given spot is passed by only one wheel at a time, giving the truck and body opportunity to cushion the effect of the change in elevation. However, it is evident from analytical reasoning and practical experience that consideration must be given to the slope of the track in the spirals to prevent too sudden a change in the vertical position of the equipment where the spirals are short.

The previously mentioned report[7] by J. C. Loach and M. G. Maycock presents results of riding tests on curves on English railroads and has used somewhat similar methods to those used for the tests here reported. They, however, recommended a maximum rate of change of elevation of 2¼ in per sec as compared to the AREA of 1¼ in per sec, and their formula for minimum length of spiral is

$$L_{min} = 0.65\ EV \tag{11}$$

which is only a little more than half the minimum length given by the AREA formula. However, they say that the value 2¼ in/sec should be decreased for the larger elevations and prefer designs giving at least 1½ times the length of spiral specified as minimum. They also require that no vertical slope greater than 1 in 300 shall be used in the spiral, that requirement prevailing over the formula when the formula indicates a steeper slope.

2. Test Results

The relations between some of the pertinent factors concerning a car traversing a curve were discussed in Sec. D. The spiral easement was shown to be an important part of a curve for promoting ride comfort. The observers on the tests were instructed to note only their sensations during the passage over the circular portion of the curves but the records being continuous gave a record of what happened to the car in the spirals. This information was used to determine the rate of change of the acceleration in the spirals. The rate of change of acceleration has been shown to be a measure of comfort for types of acceleration similar to that encountered in passing through the spiral. The lateral acceleration must change (during the time of passage through the spiral) from zero on the tangent track to the constant value given by the circular curve. (See Fig. 7a).

The rates of change found in some of the tests are plotted in Fig. 39 with respect to the frequency of occurrence of various magnitudes of rate of change. Data from six tests on five railroads are given. The test track on the KCS and the L&N was through rough territory with many sharp curves, with little room for transitions in many cases. The CMStP&P, CB&Q and AT&SF test track was high-speed track with light curves, mostly under 3 deg and longer transition curves. From the diagram it can be seen that the KCS and L&N had the greatest number of curves in the 0.010*g* per sec group, 31 percent and 37 percent, respectively. There were an appreciable number of curves up to 0.040*g* or 0.050*g* per sec. One curve had a rate of 0.125*g* per sec on the KCS. This was a 4 deg with 5 in elevation and a 115-ft spiral. The speed was 63 mph, corresponding to a calculated unbalance of 5½ in. The speed for a 3-in unbalance would be 55 mph (AREA formula).

The other tests have a large percentage of the curves in the 0, 0.005, 0.010, and 0.015 groups and very few over 0.025*g*, except for the high-speed test on the Milwaukee where curve speed limits were considerably exceeded as a test condition.

Previous discussion had indicated the possibility of a bump at the start and finish of the spiral where the upward velocity changes from zero to some finite value. Records were taken of the vertical acceleration for the L&N tests, and some indication was found of such a rough spot in some of the curves with very short spirals. However, the general vertical vibrations in this car were of considerable amplitude and made it difficult to determine the exact cause of any increase at a given location. This test was the only one in which vertical accelerations were taken, and the evidence is not such as to permit definite conclusions to be made.

3. Discussion and Recommendations

The above data give no direct information on how the degree of sensation in the spiral is related to the rate of change of acceleration. Tests were reported in the paper by Loach and Maycock[7] where this relation was directly observed on the spirals themselves and the data are shown in Figs. 8 and 9 of their report. However, these figures are in terms of Rate of Gain of Deficiency, and the rate of gain of acceleration was not apparent. Correspondence with Mr. Loach developed the fact that the acceleration was a recorded value, and he very kindly furnished copies of the two figures involving tests on curves 1 to 14 in which the recorded acceleration scale is shown. These diagrams are shown as Fig. 40. The unbalance (cant deficiency) shown in the report is evidently an equivalent value calculated from the measured acceleration rather than an unbalance calculated from the speed, curvature and elevation. The curves 1 to 14 were lined and surfaced before the tests and gave much more consistent results than another set not shown here that were not worked over. The results for the tests on the other curves are given in the report on the British tests.

The sensation numbers used by Loach and Maycock were similar to those in this report in the lower ranges, but a somewhat more detailed gradation was used for the higher ranges. Sensation zones for the British tests and the AAR tests have been given and their possible equivalence discussed and shown by Fig. 38 in Sec. D. Since such sensations are not distinguishable with a fine degree of accuracy, the practice has been in this report and others, including Meister's[2], to class a given sensation as a zone and use the numbers to define the boundaries of the zones rather than to regard the sensation as a definite number, except as representing an average for a group of observers.

Reference to the legend in Fig. 38 and to Fig. 40 indicates that a rate of gain of 0.04*g*/sec corresponds approximately to an index of 2.00, which is classed as noticeable. Loss of acceleration seems to be less disturbing, so the entering of the curve appears to be the governing factor. If we allow for the variability by taking the edge of the belt of data, a value of 0.03*g*/sec would allow a factor for imperfect conditions. This rate can logically be taken as an upper limit for establishing the minimum length of spiral based on the factor which generally determines the comfort in the spiral portion of the curve.

The AREA Manual[5] establishes the minimum length of the spiral by the equation

$$L_{min} = 1.17\ E_A V \qquad (10)$$

where E_A is the actual elevation on the curve in inches and V is the speed in miles per hour. As previously discussed the elevation is an incidental factor and important only when it reaches certain limitations which lead to very short spirals. Since we have previously established the acceptable maximum of the steady acceleration on the circular curve as 0.10*g* and have above found that an acceptable rate of attainment of that acceleration is 0.03*g* per sec, the length of the spiral can be defined directly in terms of the factors involving comfort and speed.

The minimum time which can be used to attain the 0.10*g* acceleration with a reasonable degree of comfort in passage of the spiral is

$$\frac{0.10g}{0.03g/\text{sec}} = 3.33 \text{ sec}$$

This period is required irrespective of degree of curve, elevation, or speed.

If V is to be expressed in miles per hour

$$L_{min} = 3.33 \text{ sec} \times \frac{5280 \text{ ft } V}{3600 \text{ sec}}$$

$$L_{min} \text{ (in feet)} = 4.88\ V \qquad (12)$$

The British report gives the minimum length as

$$L_{min} = 0.65\ E\ V \qquad (11)$$

which is slightly over one-half the minimum length as compared to the AREA formula. The recommendation is made in the British report, however, that at least 1½ times the formula value should be used where possible.

Attention should again be called to the fact that use of the formula $L_{min} = 4.88\ V$ assumes that the speed on the curve is sufficient to give 0.10g acceleration on the circular curve. This acceleration is approximately the amount found with a calculated 3-in unbalance for the cars with the larger amounts of roll. The fact that a constant period of time is needed for attainment of a given acceleration results in a considerable disagreement with the AREA formula in the requirements for spiral lengths in some cases. Light curves of small elevation require short spirals by the application of the AREA formula, but logical reasoning would lead to the conclusion that the acceleration the passenger feels depends on the unbalance present rather than the elevation in the track. Carrying this illustration further, a 1-deg curve with no elevation could be run at 65 mph with 3-in unbalance, but the AREA formula would indicate that no spiral is necessary. Of course this is absurd, but it is apparent that it must be decided at what point the values of the AREA formula become acceptable on the basis of comfort. The following examples will illustrate relative values by the two methods.

Assume a 1-deg curve with 1-in elevation and 3-in unbalance based on 60-in gage (75 mph).

$$\text{AREA } L_{min} = 1.17 \times 1 \times 75 = 88 \text{ ft.}$$
$$\text{Proposed formula, } L_{min} = 4.88 \times 75 = 367 \text{ ft.}$$

The distance of 88 ft at 75 mph is covered in 0.7 sec, which seems a rather short time to acquire an acceleration equivalent to 6-in unbalanced elevation if the car did not roll.

Assume a 3-deg curve with 3-in elevation and 3-in unbalance (54 mph).

$$\text{AREA } L_{min} = 1.17 \times 3 \times 54 = 189 \text{ ft.}$$
$$\text{Proposed formula, } L_{min} = 4.88 \times 54 = 264 \text{ ft.}$$

The relation has gone from about 4 to 1 in the first example to about 1.4 to 1 in this case.

Assume a 5-deg curve with 6-in elevation and the same 3-in unbalance (51 mph).

$$\text{AREA } L_{min} = 1.17 \times 6 \times 51 = 357 \text{ ft.}$$
$$\text{Proposed formula, } L_{min} = 4.88 \times 51 = 249 \text{ ft.}$$

In this last example the minimum length required by the AREA formula exceeds that dictated by the comfort relation.

The proposed formula may also be helpful in determining a comfortable speed on the basis of the spiral where short spirals must be used rather than by the unbalance on the curve.

In the case of equipment that has been found to be able to use a greater amount of unbalanced elevation because of less roll on the curves, the unbalanced elevation calculated from Eq. 9 involving the roll angle can be used rather than the usual 3-in calculated unbalance to obtain a larger value of V that will still have a suitable degree of comfort.

The values of rate of change of acceleration on several railroads have been shown in Fig. 39 and are of interest in connection with the above discussion. The rates of change shown are comparable to the $0.03g$/sec limitation given above. Where curvature was small the rates were below the recommended maximum, but where the territory was rough and curvature sharp it was often exceeded. It is apparent that the recommended limit is such that it will include much of the present practice except in extreme cases.

One undesirable practice observed in some cases is the running of the elevation into the tangent. This is sometimes done for very short spirals where the elevation is large to keep within a reasonable rate of gain of elevation or where there is no spiral and one-half the elevation is provided in the tangent and the other half on the curve. The effect of this is illustrated by the sample record shown in Fig. 14.

It is seen that a reverse acceleration with respect to that within the curve is obtained ahead of the curve and following it, and the passenger is jerked rapidly from one side to the other. This effect was quite noticeable to an observer. It was often difficult to tell when the circular portion of the curve was being traversed, but the jerk at each end was definitely rough. Generally, this reversal will give a steeper slope to the acceleration curve (greater rate of change of acceleration) than would be obtained if the elevation was only in the spiral. A spiral should be provided, even if necessarily short, and all of the elevation should be added within the spiral to avoid this reverse acceleration. A reduced speed may also be required if the spiral is so short as to produce difficulty in the vertical adjustments in the equipment in gaining the elevation.

It is believed that the above spiral formula based on tolerable comfort conditions will be of aid in judging the suitability of conditions where the best practice cannot or has not been followed rather than as a design formula. It is a limiting condition that will be tolerable, but good practice will be to use longer spirals where possible. Speed limitation can also be adjusted by this formula when the comfort for the curve is determined by the length of the spiral rather than the unbalance on the curve.

Under certain conditions, such as in a short spiral to a curve with considerable elevation, the rate of attainment of elevation may become a matter of prime importance, and the formula should be disregarded. In short spirals the length of a passenger car is comparable to the length of the spiral, so one end of the car will have considerable elevation before the other leaves the tangent. Since data are not available in these tests as to a suitable limit for slope in the spiral to give satisfactory conditions on our equipment, our judgment for the present must be based on present practice found satisfactory. One of the examples previously given on the KCS where the rate of change of acceleration was $0.125g$/sec for a speed that gave 5½ in calculated unbalance would have a rate of gain of elevation of 3.97 in/sec. The ride on this curve was in the uncomfortable range. For a calculated unbalance of 3 in (AREA formula) the maximum speed would be 55 mph and the rate would be 3.18 in/sec. It is apparent there are many curves having rates much higher than the 1¼ in/sec of the AREA formula. The proposed formula would indicate a minimum spiral length for 55 mph of

$$L_{min} = 4.88 \times 55 = 269 \text{ ft}$$

which is more than twice the actual length of 115 ft.

The British report recommends a maximum rate of gain (or loss) of 2¼ in/sec, with a further stipulation that the slope shall never be greater than 1 in 300, but would prefer to use 1½ in/sec and slope of 1 in 450. The slope in the above quoted example would be 5 in. in 115 ft, or 1 in 276, a slightly greater slope than the maximum British limitation.

F. CLEARANCE REQUIREMENTS

1. Analytical Discussion

a. *Clearance Calculations*

The determination of clearance requirements on railroads is a matter of great importance and considerable complexity. Some of the older railroads in the heavily built-up regions have clearance limitations carried over from early construction that would be very expensive to eliminate. As a matter of safety it is necessary to determine what equipment may be sent over a given line and the speed at which it may be run. Also, in the case of freight shipments of large size a decision must be made in regard to acceptance and routing. Clearances on tangent track present little difficulty and may be calculated with good accuracy. The calculations with respect to curved track require assumptions which have not heretofore been experimentally checked under dynamic conditions.

The advent of the modern type streamlined passenger car with its greater spring travel, higher speeds and other changes in design has in some cases caused trouble and has increased the need for more definite information concerning certain factors in regard to validity of clearance calculations. Some large freight cars with greater height may require clearances as great as the relatively longer passenger cars, and specially large shipments are often a problem.

The calculation of clearance requirements for passenger cars involves the following factors:

1. The width of the car.
2. Overhang at end of car due to the curvature.
3. Overhang at middle of car due to the curvature.
4. Lateral play in truck parts and play between wheel and rail.
5. Displacement of the car body due to track elevation, tilting on the springs, and swing hanger movement resulting from unbalanced elevation at various speeds.
6. Allowance for variations in track center spacing and for the effect of track irregularities.

All these factors except 5 and 6 can be readily determined from the geometry of the parts or by direct measurements in the shops and will not be discussed here except incidentally.

Factor No. 5, the lean of the car body, was one of the measurements taken for the ride comfort tests, and that data have been analyzed to give information regarding the calculation of dynamic displacement values. A formula has been proposed[8] that involves the static lean of the car as one of the factors in determining the displacement or throw under running conditions. To check the validity of this method of calculation, static lean tests were made on all but two of the cars tested for ride comfort. The results of these lean tests will be given later.

The proposed formula previously mentioned for calculating the throw of the car body on a curved track is

$$T = CV^2D \qquad (13)$$

where

T = Horizontal throw in feet, measured from the position at rest on the curve to position taken at speed V.
V = Speed in miles per hour.
D = Degree of the curve in question.
C = A constant involving the measured lean of the equipment.

The constant C is defined by the formula

$$C = \frac{L}{V_e^2 D} \tag{14}$$

where

L = Horizontal displacement of the car body in feet, measured from a perpendicular to the plane of the rails (the lateral play is included in this value).
V_e = Equilibrium speed for any curve in question.

It is recommended in the reference that the lean be measured for an elevation of one rail of 6 in.

Since D, the degree of curve, occurs in the expression for both T and C, the formula can be simplified by substitution for C

$$T = \frac{L}{V_e^2 D} \times \frac{V^2 D}{1} = L\left(\frac{V}{V_e}\right)^2$$

Also from Eq. 1

$$V_e^2 = \frac{E_R}{D \times 0.00070}.$$

In this case $E_R = E_A$ for the particular curve and

$$V_e^2 = \frac{E_A}{D \times 0.00070}$$

and

$$V^2 = \frac{E_A + E_U}{D \times 0.00070}$$

Substituting

$$T = L\left(\frac{E_A + E_U}{0.00070\,D}\right) \times \frac{0.00070\,D}{E_A} = L\left(\frac{E_A + E_U}{E_A}\right)$$

or

$$T = L\frac{E_R}{E_A} \text{ (E_R in this case is the required elevation for equilibrium at speed V)} \tag{15}$$

It should be borne in mind that this throw, T, is measured from the position of the car "at rest" on the curve. If Eq. 15 is to be used for curves with elevations different from those for the static lean tests, an interpolated value of L must be used, and this new "at rest" position used as the base for obtaining throw of T under various dynamic conditions. It is evidently intended in the committee report[8] to prorate the lateral play for various elevations, and this assumption will generally not cause much error.

A simpler and more easily used procedure would be to determine from the lean tests the displacement L for the unbalanced elevation, positive or negative with respect to the normal to the plane of the track. That is, the displacement R due to roll will be

$$R = L\frac{E_U}{E_S} \text{ (}R\text{ also includes a proportional amount of lateral play)} \quad (16)$$

where E_S is the static lean test elevation and would preferably be considered of positive sign. This then is the displacement due to roll and lateral play from the perpendicular to the plane of the inclined track and can be added to or subtracted from the other displacements according to an assumed convention of signs. If displacement inward of the curve is negative, a negative E_U will increase the lean inward and vice versa. The displacement due to the track elevation would be negative by this convention.

The lateral play may reach an appreciable amount. A listing of this play from the American Railway Car Institute indicates a total of $4\frac{7}{16}$ in is possible where all the play is taken out in one direction. It is stated that the values of play listed below are used jointly by the Institute, the Budd Company, Pullman, and American Car and Foundry.

Center plate to center plate	¼ in
Bolster to frame	2½ in
Pedestal liner to box	$\frac{3}{16}$ in
Inside of box	⅞ in
Wheel to rail and wheel wear	⅝ in
Total	$4\frac{7}{16}$ in

The lateral play actually measured in the static lean tests was 0.69 in to 3.00 in. The above values are evidently maximum allowable amounts.

Another assumption in the use of the equations above is that the effect of the unbalanced elevation in the static test which causes a lean inward of the curve is equivalent to the effect of unbalanced elevation outwardly of the curve from the centrifugal force under dynamic conditions. In addition to any general average equivalence between the static and dynamic case, allowance must, of course, be made for the effect of track irregularities and oscillatory action of the car always present to some degree under dynamic conditions. In a following article the running test data will be presented for comparison with the static lean tests, so the suitability of the above proposed method of calculating the lateral throw may be judged.

2. Static Lean Test Results

a. *Measured Static Lean of Car Body*

The first static lean tests were made on actual curved track, but this was found to be inconvenient and an unnecessary refinement. For later tests the cars were run up on oak shims of various heights placed under one side. Measurements were taken by which the lateral displacement and car body roll could be determined. All measurements indicated by letters in Fig. 41 were taken with the car sitting on level track, and the wheel base and truck center distances were also measured. After these measurements were taken the car was elevated to a height of 2 in and measurements, A, B, K, L and V were made. These last 5 measurements were then repeated for the additional elevations of 4 and 6 in. When oak shims were used to gain the necessary elevations, their height was not measured until after the car was removed from the shims because the weight of the car resting on the shims compressed them to slightly less than their original height.

Measurement B was taken level with the rail head and out from the edge of the wheel. Measurements A, B, K, L and S are made at truck centers, while G, T, U and E are taken at or along the wheels and axles. The height of the center plate was taken from manufacturer's drawings of the trucks.

The lateral play displacement was determined from lean test measurements as follows:

$$\text{Lateral play displacement (inches)} = (B + \frac{U}{2}\cos\alpha) - (K\sin\alpha + \frac{W}{2\cos\beta}) \qquad (17)$$

$$\text{where } \alpha \text{ (degrees)} = \text{track angle} = \sin^{-1}\frac{\text{Elevation (inches)}}{60}$$

$$\beta \text{ (degrees)} = \text{car angle} = \sin^{-1}\frac{A}{S}$$

The displacement due to roll of the car is calculated by multiplying the distance from the center plate to the eaves by the sine of the track angle α minus the car angle β. Expressing this as an equation

$$\text{Roll displacement} = \text{Sin } (\alpha - \beta) \text{ (Eaves height—center plate height)} \qquad (18)$$

where eaves height $= L$ (on level track and all values are given in inches)

The sum of the lateral and roll displacements at the eaves is later correlated with the displacements obtained from the running tests. The lateral displacement used for any particular curve on the running tests is the same as the interpolated lateral displacement from a lean test where the elevation on the lean test is equal to the calculated unbalanced elevation for that curve on the running test. For example, if a car has a calculated unbalanced elevation of 3 in, the lateral displacement was taken to be equal to the lateral displacement on a static lean test where the elevation is 3 in.

The results of the static lean tests are given in Table 3. All displacements in this table are converted to a common height of 10 ft for the purpose of direct comparison. The lateral displacement due to the play and swing hanger movement is given for each elevation, the lateral displacement due to roll of the car body, the angle of roll and the total displacement due to both. The lateral for the 6-in elevation is from about 0.6 to 3.00 in for the several cars, and the roll displacement about 3 to almost 6 in, the CB&Q dome car being low in both instances. It also had a small roll angle, 1.4 deg. Three values of total displacement over 7.00 in are shown, these being the KCS, AT&SF without a roll stabilizer, and PRR cars. The dynamic tests indicate the KCS car should have shown more displacement in the static lean test. The AT&SF car of this type normally uses a roll stabilizer, and when a similar car having the roll stabilizer was tested the displacement was only 4 in. The greatest roll angle was about twice the least in the static tests.

b. *Correlation of Static Lean with the Dynamic Car Roll*

The roll of the car body is the difference between the inclination of the track and the inclination of the body of the car. The position of the body with respect to the vertical, as previously discussed, was measured in the running tests by the gyro and recorded graphically. This angle can be used to determine the displacement due to roll if we know the elevation on the curve. This method of determining the displacement due to dynamic roll does not include the lateral displacement due to play in the parts. If this lateral play were added to the displacement due to roll, the displacement under static and dynamic conditions can be compared. This has been done in the manner previously described for most of the tests, and the results plotted in Figs. 42 to 50, incl., with respect to the calculated unbalanced elevation. The maximum amount of the lateral was taken from the measurements for the greatest elevation in the static tests and prorated relative to the calculated unbalanced elevation. It should be borne in mind, as previously discussed, that the accuracy of the calculated unbalanced elevation is dependent on the correctness of reported elevations and curvatures on the track charts. The static lean tests are plotted as negative unbalances, since there are also negative unbalance values for some of the curves in the running tests. The car body displacement is inward for negative values of unbalanced elevation.

Inspection of the diagrams for the several tests show various degrees of correlation. The objective is to determine whether the static lean test will indicate with sufficient reliability the displacement for any given dynamic condition. To be so usable a straight line through the origin of the coordinates should represent the average slope of both the static and dynamic test values. The dynamic values, of course, are more numerous and can be expected to show more range of variation because of track irregularities, dynamic oscillations of the car and any inaccuracies in the data on the track plans.

The best correlation is shown in the diagram for the high-speed tests on the Milwaukee (Fig. 49), where the points for the static and dynamic tests lie quite close to the average line. Thus the displacement indicated by a 3-in static lean would be 3.4 in at the eaves and the same 3.4 in. in the other direction for 3 in unbalance when running, with about ± ½ in range in the displacement from the average in the running test. The static lean tests were made in the morning and the running tests in the afternoon of the same day. The runs were made over about 50 miles of track on which some of the curves had been checked and relined just previous to the test and a wide range of speeds was used. The test car was also placed between two similar cars in the train. In most of the other tests a considerable period elapsed between the static and dynamic tests, and the test car was in most cases next to the head-end equipment or other dissimilar equipment. These conditions increased the likelihood of differences in the manner of action of the car for the dynamic and static tests.

Also plotted as crosses on the Milwaukee diagram are values of throw T calculated from Eq. 16, using as the origin of plotting the prorated static lean position for an elevation E_A, for the curve in question. It is seen that the correlation for all the points is quite good. The quality of the correlation can be expected to be somewhat similar to the correlation obtained for the test points which is partially dependent on the accuracy of the track data.

The displacements for the PRR car are given in Fig. 50 and show good correlation with an average line, and a 3-in unbalance gives about 4.0-in displacement with about ± 1 in scatter from the average line. Two sets of points are plotted for the PRR static lean tests that represent the displacements for the stub and vestibule ends of the car. The displacement was considerably greater at the stub end (about 1¾ in difference due to roll only for 6-in elevation) than the vestibule end. The springs on the vestibule end were almost ⅓ stiffer than at the stub end, and this is probably the source of the difference. This difference in roll displacement would involve a twisting of the car body, giving a relative movement of 1¾ in at the eaves between the center pins. It is seen that the lean displacement values for the stub end lie nearest the average line for the dynamic values. Apparently the dynamic action corresponds more nearly to the results for the softer springs, and it would be safer to assume the greater clearance was needed as indicated by those values. The limit of travel on the bolster was also reached between 4 in and 6 in elevation at the vestibule end in the static test, which may have had some effect in reducing the lean at that end at the 6 in elevation.

The Burlington dome car, Fig. 43, showed fair correlation and had low values of displacement as indicated by the steeper slope of the average line. There was also some scatter in the dynamic values. The lower static elevations had greater than proportional displacements, probably due to the lateral play being taken up at the lower elevation. Using the average line, a 3-in unbalance would give only about 2.3-in displacement at the 9-ft 8-in eaves, but there is almost ± 1½ in scatter which should be considered in calculating clearance requirements.

The Santa Fe car with the roll stabilizer shows a dynamic lean of 2.2 in for 3-in unbalance, with good correlation for the dynamic values and the static values. The same car without the roll stabilizer had 4.0-in displacement for the 3-in unbalance, and also had good correlation with the static lean displacements, though for some reason the static roll angle was not as large as expected. A 3-in unbalance would give about 4-in displacement, and the scatter is about ± 1 in.

The New Haven car (Fig. 48) with outboard swing hangers gave excellent performance in going around curves as judged by criteria previously discussed. There was little roll and a correspondingly smaller lateral acceleration. The displacement correlation with the lean test, however, is not as good as some of the others. There are few dynamic values greater than 3-in unbalanced elevation, and the points have about ± 1 in range in displacement. The displacement at 3-in unbalanced elevation is only 2.65 in. The static lean points are not linear, the lower elevation having a lesser displacement relatively than the higher elevations. Such a relation could be due to the fact that all the lateral had not been taken up at the lower elevation and possibly not at the maximum of 5.88 in, since the static displacement at that elevation is less than the value from extrapolation of the average line for the dynamic values. A considerable time had elapsed between the running and static lean tests, so it is possible that the car was in a somewhat different condition for the two tests or that some restraint was present under the static conditions that prevented as much displacement taking place as when the car was in motion.

The two DL&W cars, which were quite similar except that one had inboard and the other outboard hangers, had shown some scatter in previous plotting. The speeds were low, few points being over 3-in unbalance and about three-fourths of them below 2-in unbalance. The diagrams for displacement have similar characteristics. The two sets of static lean test points lie on a line (except one) which goes about through the middle of the spread of dynamic values. One static lean point, the 6½-in elevation on the inboard hanger car, has too small a displacement to lie on the line with the other two points as if some binding or restraint had prevented full roll for the highest elevation. The outboard hanger car had 3.25-in displacement at 3-in unbalance and the inboard car 3.75 in. These two cars had previously shown similar action as judged by the criteria used in Table 2. The stiffness of the bolster and equalizer springs was greater on the inboard hanger car than on the outboard hanger car.

A characteristic of the recorded acceleration that may have some bearing on the lack of uniformity of the results was the reverse acceleration prior to entrance of numerous curves on the DL&W as would be caused by running the elevation onto the tangent. This practice is generally unnecessary, and it is usually better from the standpoint of comfort to use a steeper slope in the spiral and keep the tangent level transversely. The jerk from the reversal of the acceleration at entrance and exit of the curves was much more noticeable than the acceleration within the curve. The rate of change of acceleration during the reversal of acceleration is generally greater than the rate within the spiral itself if the elevation was placed only in the spiral. Evidence was presented in Sec. E—Transition Spirals, showing that comfort is dependent on the rate of change of acceleration in the spiral. There is probably also an additional discomfort due to the passenger being forced first one direction than the opposite.

The Kansas City Southern test covered a good range of speeds, and the car showed considerable roll. The plotted points for the dynamic tests have a good grouping around the average line. The static lean test on this car was the first one made, and the car was tested on 2 curves with about 6-in elevation, but no intermediate elevations were available. The displacements in the two tests with the 6-in elevation fall considerably short of corresponding to that indicated by the average line of the dynamic tests. The only explanation that can be offered is that there was some jamming in the truck parts that restricted the full roll in the static test which would otherwise have been large, but the vibration in the running tests kept the jamming from taking place. The average line indicates a displacement at the eaves of about 4.5 in for a 3-in unbalance.

All the diagrams for displacement shown above are with respect to the eaves or critical point for the given car. The heights of this point were from 9.5 ft to 11.2 ft above the top of the rail. The static lean values given in Table 3 were corrected to a common height of 10 ft. It should be borne in mind that the displacements plotted in the above mentioned diagrams include the lateral play as found in the static lean tests in addition to the displacement due to dynamic roll. The lateral play was prorated according to the calculated unbalanced elevation. The play varied considerably in the several cars.

3. Discussion and Recommendations

The foregoing discussion and data indicate that there is a reasonable correlation between static and dynamic roll and that the static lean tests can be used for estimation of clearance requirements if the tests are properly made and some judgment applied to the use of the lean test results. It does not seem safe to rely on the results of a single elevation, however. The reported tests show that it is possible to get a result from a single test that could lead to erroneous conclusions if running tests were not available. It is also evidently necessary and logical to add to the deflection from the average line the clearance allowance that would be necessary because of the effect of track irregularities and car oscillations. A survey of the gyro records for the tests was made to determine the clearance allowance that would be necessary because of the effect of track irregularities and dynamic action of the cars under normal operating conditions. It was quite evident that the variations in the roll were dependent to a large extent on speed, though some cars showed less roll variation than others. Under 60 mph the variation in roll was generally not over ± 0.5 deg. Up to 90 mph variations of ± 1.0 deg were usual, and on the high-speed Milwaukee run the roll variations were ± 2.0 deg at 110 to 112 mph. The curves had about the same amount of variability as the tangent. It will be necessary to allow corresponding clearance for these variations in roll.

All the tests here reported were made with cars in normal operating condition. After all the normal clearance requirements are added together to give what might be termed a minimum value, it is, of course, necessary to add an allowance for abnormal conditions, such as a broken spring.

The lean test procedure as used for the later tests was relatively simple and usually took only about one-half day for three elevations. There has been some discussion of provision of facilities for such tests by the AAR at its Research Center or at some central terminal location. Data of this nature would also be of value for some freight equipment and locomotives.

G. CONCLUSIONS

1. Ride Comfort on Circular Curves

The present basis for speed limitations on curves and curved track design practices were established considerably before the advent of the present streamlined passenger equipment with its increased operating speeds and modern design. These limitations were based on analyses and practical experience, but there has been no experimental data to check their suitability either past or present. The tests here reported are for the purpose of checking the present suitability of these practices and establishing a logical scientific basis for future use.

Since it was found that no experimental data were available on what constituted a good or bad ride for this type of acceleration in terms of definite physical quantities, it was necessary to establish such a correlation by direct observation. This was done by the use of observers in two sets of tests to measure the lateral acceleration and passenger sensation of comfort. This relation, which is shown in Fig. 8, was quite definite and can be used as a basis for ascertaining ride comfort in equipment tests by instrumental readings only. The tolerable acceleration for a reasonable degree of comfort was found to be 0.10*g*, with some allowance for variability of track and equipment. This acceleration corresponds to a Ride Index of 2.00, which is the threshold of the Strongly Noticeable zone of comfort and limit of the Noticeable zone.

The tests also showed that the passenger was getting much more acceleration than the calculated unbalanced elevation indicated should be present. Measurements of the angular position of the car body showed that the body rolled enough to counteract the beneficial effect of the track elevation, and in some cases the body was almost vertical. This roll was a prime factor in the comfort on curves, and the test program was planned to include such features as would be most likely to affect it. The tendency to roll is promoted by the softer, long-travel, modern springs and some features of swing hanger design, but the softer springs are an important factor in obtaining satisfactory vertical ride and will undoubtedly continue to be used. The following features were found to control the roll to about an equal extent.

a. *Outboard swing hangers.* They in effect establish a broader base of spring support on the car body and have other desirable advantages.

b. *Roll stabilizers.* The action of the stabilizer is to equalize the bolster spring deflections, and they do so effectively. However, the stabilizers complicate the design of the truck and require additional maintenance.

c. *Stiffer vertical springing.* This will give poorer vertical ride and can only be applied for partial correction.

Table 2 compares the various cars by several methods and indicates the effectiveness of these various features.

The cars may be rated as to their ability to go around the curves with a suitable degree of comfort on the basis of their roll. A simple equation involving the roll angle Θ for 3-in unbalance and E_{cu} the compensated unbalanced elevation

$$E_{cu} = \left(\frac{6.0}{3 + 60 \sin \Theta}\right)3 \qquad (9)$$

is proposed for this purpose. The speed for a given curve may then be calculated from this value of E_{cu}. Since it is generally not feasible for each road to make running tests, a simple lean test may be used to obtain the roll angle as it was shown that the static lean test values usually agreed fairly well within the average dynamic values on the basis of the calculated unbalanced elevation, E_u. The static values tend to be a little less than the dynamic values in some cases, and it would seem best to use a small factor of safety. It was recommended that at least three elevations, 2, 4 and 6 in, be used in the static lean tests so it can be judged if all lateral play is taken up and if the car body is moving freely. Use of a still larger elevation and readings on the return may also be advisable in view of some discrepancies previously mentioned.

The table of recommended speeds in the Manual is based on an unbalance of 3.00 in. This unbalance is suitable for the cars with the larger amounts of roll, but some cars, as shown in Table 2, can maintain the same degree of comfort for over 4.00 in unbalance and their speed can be increased somewhat.

The AREA Manual table of recommended speeds has been calculated from the formula

$$E_R = 0.00066\, V_e^2 D \tag{1}$$

Considerably better correlation was found between the calculated unbalanced elevation and the test values using the formula

$$E_R = 0.00070\, V_e^2 D \tag{2}$$

It is recommended the table be recalculated on this basis.

2. Transition Curves

The transition portions of a curve are very important to the riding comfort; too short a spiral can be uncomfortable. Records of the lateral acceleration gave data for obtaining the rate of change of acceleration in the various tests. No direct observations were made by the observers of comfort in the transitions but data from British tests[7] were available and show good correlation with the rate of change of lateral acceleration in the spiral. A rate of 0.03*g* per sec was selected as an acceptable maximum for reasonable comfort. This corresponds to a ride index of 2.00 (British tests) noticeable, using the upper edge of the band of the plotted points to allow for variability. This rate is the factor that governs the comfort within the spiral and can be used to define the length of the spiral directly if an upper limit of the steady acceleration such as 0.10*g* on the circular portion of the curve is established. The combination of these two limits of toleration gives the equation

$$L_{min} = 4.88\, V \tag{12}$$

where L_{min} is in feet and V in miles per hour. The above assumptions must be met to use the formula correctly or the equation coefficient adjusted to fit other assumptions. The basic consideration in this formula is that the comfort in the spiral is primarily dependent on the amount of the unbalance (lateral acceleration) and its rate of change in the spiral. With these factors determined, a constant period of time is indicated for passage of the spiral under all conditions. The speed, elevation, and curvature are incidental to this requirement. An application of the AREA formula to a curve with no elevation indicates that no spiral is needed. This result is obviously incorrect, but it is apparent that similar application of the AREA formula to curves with small elevation may lead to designs of spirals that have insufficient lengths. This is illustrated in the examples given in Sec. E, Art. 3. It is seen there that on a 1-deg curve with only 1-in elevation, the spiral indicated by the AREA formula is only one-fourth that dictated by comfort considerations. Where the curvature was 5 deg and elevation 6 in, the AREA formula indicated a greater length than the minimum comfort requirement. In view of the

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importance of these conclusions it would be desirable to obtain more extensive data on the tolerance rate of change of this type acceleration than is at present available.

Fig. 39 indicates that a rate of change of $0.03g$ per second is a realistic value. This is obtained in everyday practice and exceeded on an appreciable number of the curves. The design of curves and speed restrictions where this rate is exceeded, could well be looked into for improvement of the ride.

One very undesirable condition that was observed on a number of curves was reversal of the lateral force on the entrance and exit portions of the curves, as shown in Fig. 14. It was judged that this resulted from carrying the elevation onto the tangent. This reversal will generally result in a greater rate of change of acceleration than if the elevation was all attained within the spiral and the passenger will be thrown one way and then the other. The elevation should only be placed within the spiral, even if this results in a short spiral. Speed reduction may be required for cases where the vertical slope is beyond the limit required for vertical adjustment of the car to the change of slope.

The rate of attainment of elevation was shown to be incidental to the problem of spiral length except in very short spirals. In this case there is the problem of a possible "bump" at the point of spiral where the vertical velocity changes from zero to some constant value. The equipment must have a suitable distance to adjust to this change. The British report sets a limit to steepness of slope in the spiral of 1 in 300. The data in this report is not suitable for drawing conclusions in this matter.

3. Clearances

Information was previously lacking on the dynamic roll of passenger cars, and it was desirable to relate this roll to clearance calculations for modern cars. Static lean tests made on nearly all the cars were correlated with this roll under operating conditions. Most of the tests indicated that there was good correlation of the static and dynamic tests on the basis of calculated unbalanced elevation. This unbalanced elevation was obtained by the revised formula using 60 in instead of 56½ in for determining the track angle.

The proposed formula

$$T = CV^2D \tag{13}$$

would be better revised to

$$T = L\frac{E_R}{E_A} \tag{15}$$

as discussed in Sec. F. The throw T is measured from the "at rest" position for the elevation in question and it would probably be more convenient to refer the displacement R due to roll to the vertical normal to the plane of the track by the equation

$$R = L\frac{E_u}{E_s} \tag{16}$$

This is also discussed in Sec. F. Since the lean test measurements of throw or displacement include the lateral movement due to play and bolster displacement this equation distributes the lateral movement proportionately to the unbalanced elevation, E_u, an assumption that will have some error but is probably sufficiently close.

The discrepancies appeared to be due mostly to lack of freedom of the car to move in the static tests or to the lateral play not being all out for the elevation used. For this reason it seems essential that a least three elevations (2, 4 and 6 in) be used to judge the validity of any static lean tests for this use. Consideration should also be given to methods that may improve the accuracy of the static lean tests.

The results indicate that static lean tests can be used in conjunction with the calculated unbalanced elevation to calculate that portion of the clearance that is required by the roll of the car body under running conditions. Since the static lean values of roll were in some cases somewhat less than the dynamic values, some moderate allowance should be made where only static values are available.

A survey of numerous records for the variability of the car body roll in running along the track showed that variations up to ± 1 deg roll occur at speeds up to 90 mph, presumably because of variations in track, line, surface and elevation, and the dynamic behavior of the equipment.

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TABLE 1 - MECHANICAL DATA ON CARS

Railroad	Car No.	Light Car Weight Pounds	TRUCKS			SWING HANGERS				BEARINGS	
			W. B. Feet	Ctrs. Feet	Snubbers	Type	Offset inches	Upper Ctrs. inches	Angle degrees	Wheel Roller Type	Side Ctrs. inches
KCS	236	103050	9.0	59.5	V	IB	3	52	6		55.5
CB&Q	4725	148700	8.5	59.5	V	IB R.S.	3.88	52	7	Timken	52
AT&SF	2882	126190	9.0	59.5	V	IB R.S.	3.0	52		Timken	51.5
AT&SF	Pine Rapids	142000	9.0	59.5	V	IB	3.00	52	6	Timken	52
DL&W	321	121200	8.5	59.5	V	OB	2.75	89	7		52
DL&W	305	128600	8.5	59.5	V	IB	3.00	52	7	Hyatt	52
NYNH&H	8673	124700	8.0	59.5	V	OB	2.50	89	7	Fafnir	55.5
NYNH&H	8510	108000	8.0	58.7	N	IB	2.75	55.5	7	Fafnir	58
CMStP&P	457	130460	8.0	56.7	V&L	N				Timken	60
PRR	4156	141030	8.5	59.5	N	IB	1.50	52	3	Hyatt	52

TABLE 1 - MECHANICAL DATA ON CARS (Cont.)

Railroad	BOLSTER SPRINGS				EQUALIZER SPRINGS			
	DEFLECTIONS			Load Rate lb/in.	DEFLECTIONS			Load Rate lb/in.
	Light Ld.	Max. Ld.	Reserve		Light Ld.	Max. Ld.	Reserve	
KCS		6.625	3.38	2980	3.63	4.00	2.13	6080
CB&Q	6.27	6.62	2.53	4620	3.77	4.17	1.68	8850
AT&SF		6.75	2.75	3440		3.50	2.75	7340
AT&SF	6.00		2.69	4150	4.00		1.75	7400
DL&W	5.75	6,37	2.87	3800	4.75	5.19	2.56	5600
DL&W	4.48	4.92	2.06	5500	3.63	3.94	1.81	8040
NYNH&H	5.75		3.00	3880	4.75		3.06	5600
NYNH&H	3.75		3.50	6030	2.25		2.25	10250
CMStP&P	5.68		6.63	2900	3.25		3.25	6960
PRR	6.10		2.84	4500	3.38		2.00	9840

All cars have 4 wheel trucks.
IB - Inboard Swing Hanger
OB - Outboard Swing Hanger

N - None
V - Vertical
L - Lateral

RS - Roll Stabilizer
WB - Wheel Base

TABLE 2

VARIOUS VALUES INDICATIVE OF PASSENGER CAR PERFORMANCE

Railroad	Car Data	Dynamic Tests: CUE at 0. 10g LA	Dynamic Tests: RI for 3 in. CUE	Dynamic Tests: Diff. TA-CA Degrees for 3 in. CUE	Static Lean Tests: Roll Angle Degrees 3 in. Elev.	Static Lean Tests: Lat. Displ. 3 in. Elev.	Static Lean Tests: Roll Displ. 3 in. Elev.	Static Lean Tests: Total Displ. Inches 3 in. Elev.
KCS	No Stabilizer	2. 90	1. 85	2. 4	2. 4*	0. 98	2. 15	3. 13
CB&Q (Dome Car)	Roll Stabilizer	4. 30	1. 40	1.2	1. 4	0. 35	1. 60	1. 95
AT&SF	Roll Stabilizer	4. 20	1. 45	1. 1	0. 8	0. 72	1. 28	2. 00
AT&SF	No Roll Stabilizer	3. 00	1. 80	2. 1	1. 8	1. 18	2. 63	3. 81
DL&W	Outboard	4. 00	1. 47	1. 7	1. 4	1.23	1. 50	2. 73
DL&W	Inboard	4. 40	1. 40	1. 7	1. 8	0. 96	2. 63	3. 59
NYNH&H	Outboard	3. 60	1. 57	1. 4	0. 9	0. 55	1. 75	2. 30
NYNH&H	Inboard	3. 90	1. 50	1. 5	NO LEAN TEST			
CMStP&P	1947 Truck **	3. 20 3. 30	1. 73 1. 66	1. 3 1. 8	1. 4	1. 50	1. 60	3. 10
PRR	Leaf Springs	2.80	1. 87	2. 0	1. 9	0. 61	2. 87	3. 48
L&N	Old Style Truck	3. 77	1. 53	Not Meas'd	NO LEAN TEST			

RI - Ride Index
CUE - Calculated Unbalanced Elevation
LA - Lateral Acceleration
TA - Track Angle
CA - Car Angle
* - From Running Test
** - Special High Speed Test

TABLE 3. RESULTS OF STATIC LEAN TESTS

Railroad	Car Data	DISPLACEMENT IN INCHES									ROLL ANGLE DEGREES		
		Elevation in Inches									Elevation in Inches		
		2			4			6			2	4	6
		Lat.	Roll	Total	Lat.	Roll	Total	Lat.	Roll	Total			
KCS	IB	NO LEAN TEST						2.00	5.1	7.1			2.9
CB&Q	Dome R. S.	.25	1.92	2.17	.42	2.56	2.98	.58	3.03	3.61	1.2	1.6	1.9
DL&W	IB	.88	2.62	3.50	1.49	4.13	5.62	1.9	4.82	6.72	1.4	2.2	3.2
DL&W	OB	.61	2.42	3.03	1.71	2.66	4.37	3.04	3.15	6.19	1.3	1.4	1.7
NYNH&H	IB	NO LEAN TEST											
NYNH&H	OB	.19	.75	.94	.42	2.14	2.56	1.10	3.5	4.6	0.5	1.3	2.2
AT&SF	IB No R.S.	.92	1.02	1.94	2.08	3.15	5.23	2.40	5.50	7.90	0.7	2.2	3.5
AT&SF	IB R. S.	.50	.91	1.41	.62	1.84	2.46	1.44	2.56	4.00	0.5	1.0	1.4
PRR	Leaf Spring	.33	2.15	2.48	.83	5.1	5.93	1.23	5.87	7.10	1.1	2.7	3.1
CMStP&P	Spec. Type	.80	1.87	2.77	1.51	2.82	4.33	2.92	3.90	6.82	1.2	1.5	2.1

R. S. - Roll Stabilizer
OB - Outboard Swing Hanger
IB - Inboard Swing Hanger

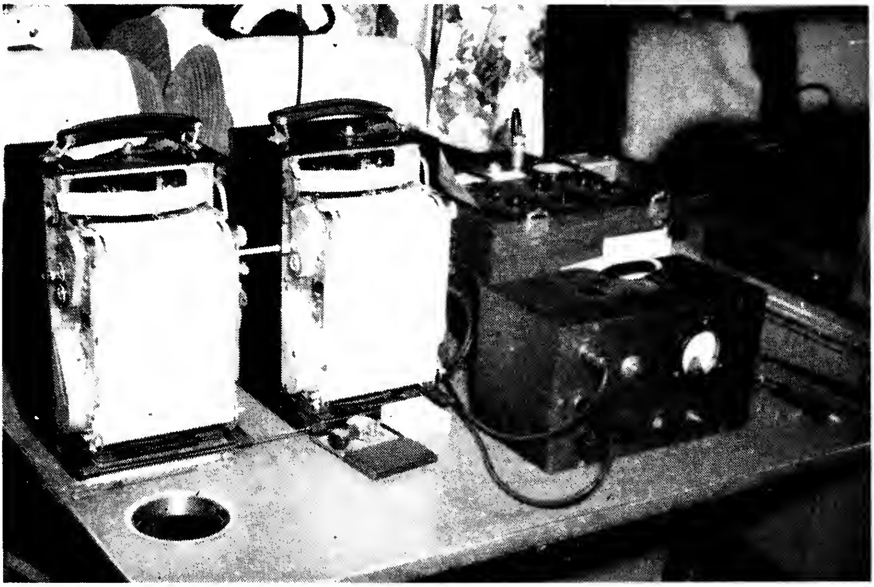


Fig. 1—Lateral accelerometer amplifier and recorders.

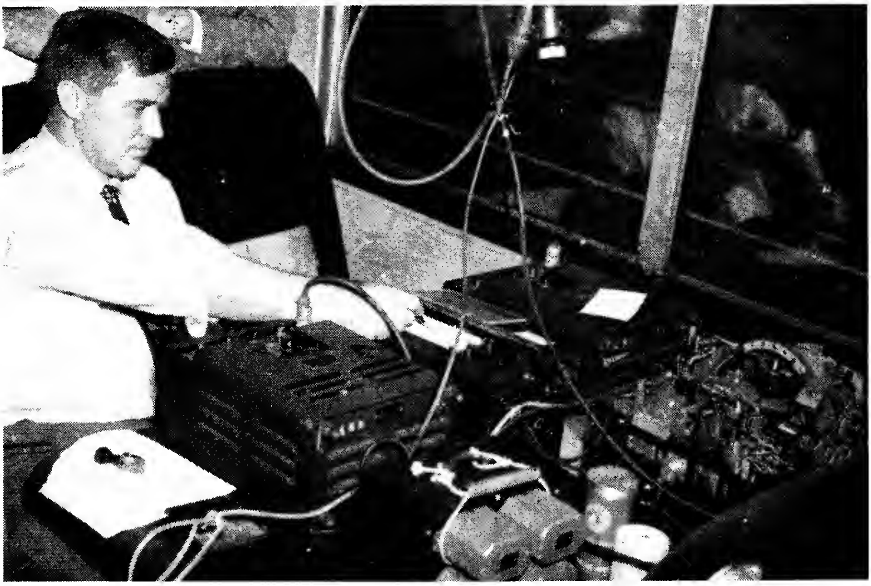


Fig. 2—Pen-writing oscillograph, amplifiers and gyro.

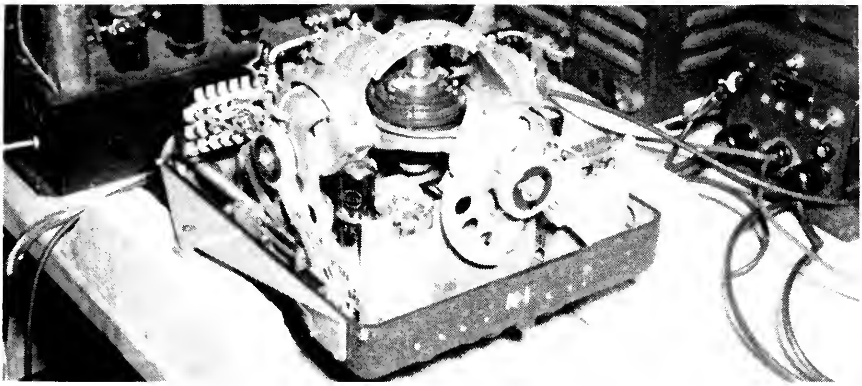


Fig. 3—Gyro roll indicator.

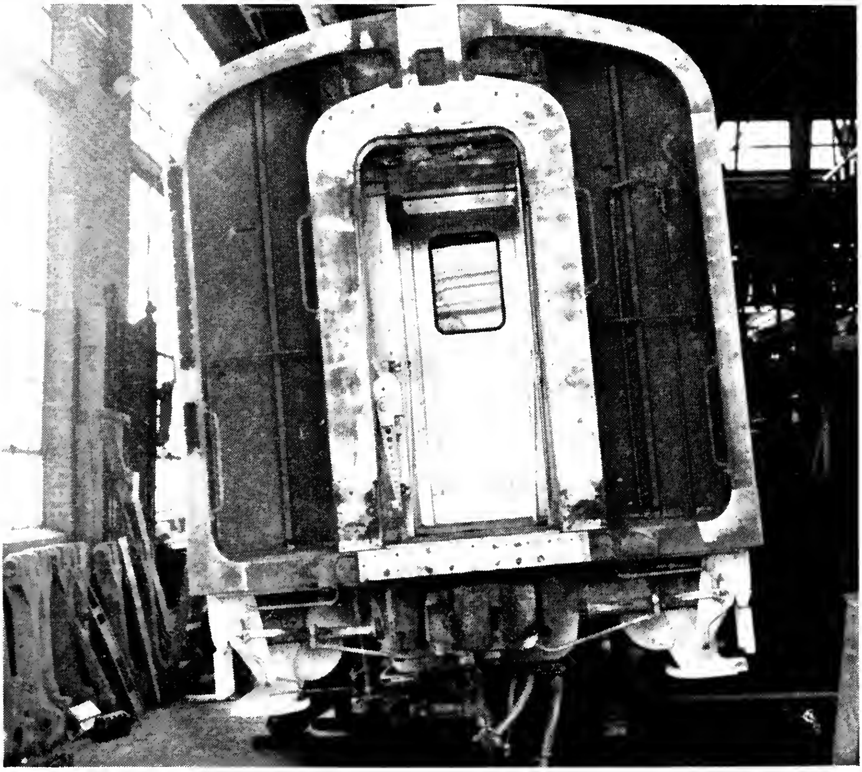


Fig. 4—Burlington dome car elevated 6 in on one side for lean test.

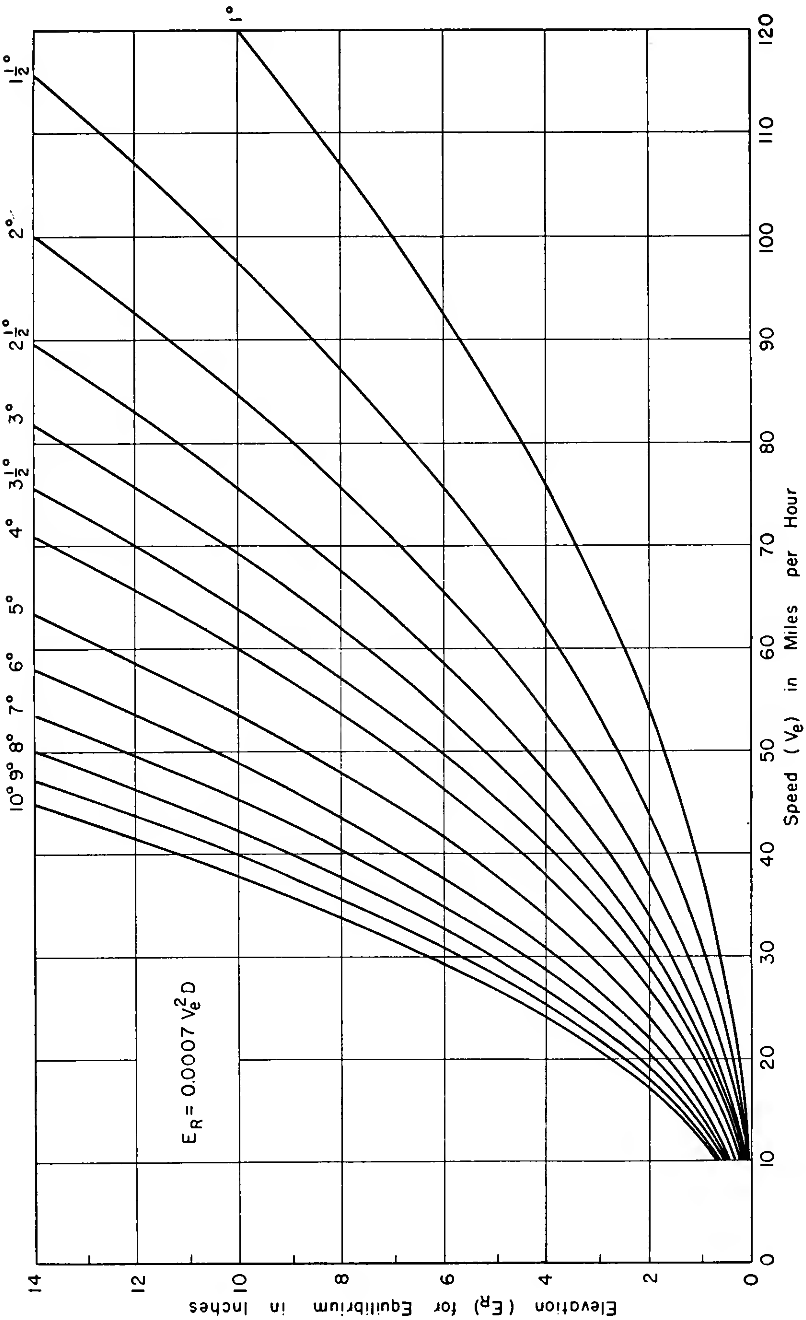


Fig. 5 - Elevation, E_R, Required for Equilibrium for Various Speeds and Curvatures

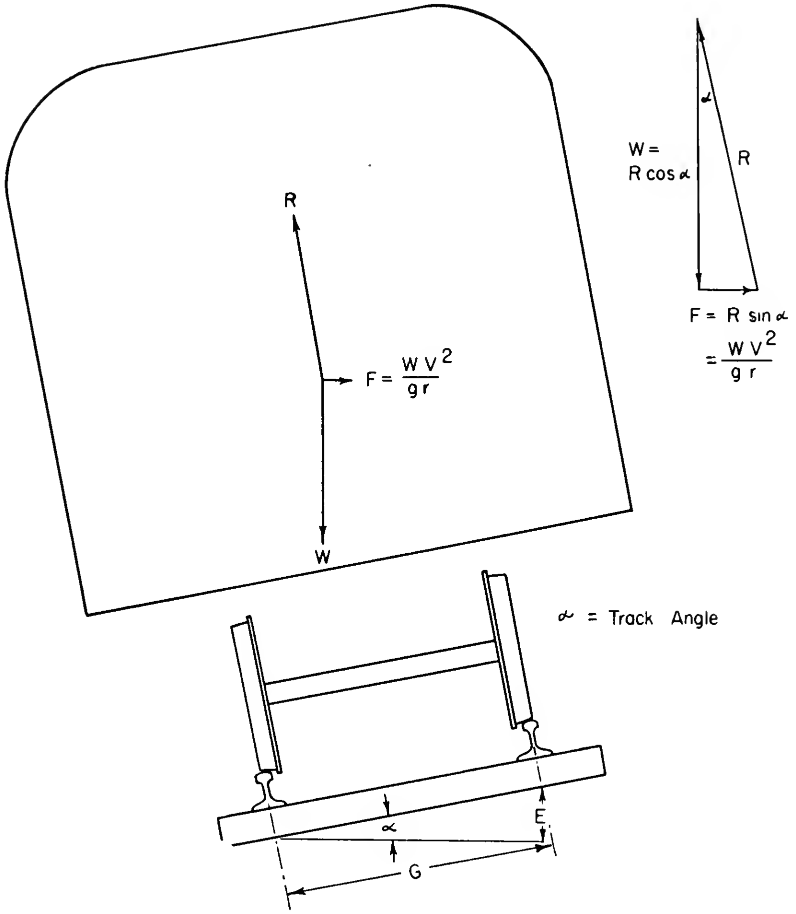


Fig. 6 - Forces on a Car Body Traversing a Curve at Equilibrium Speed.

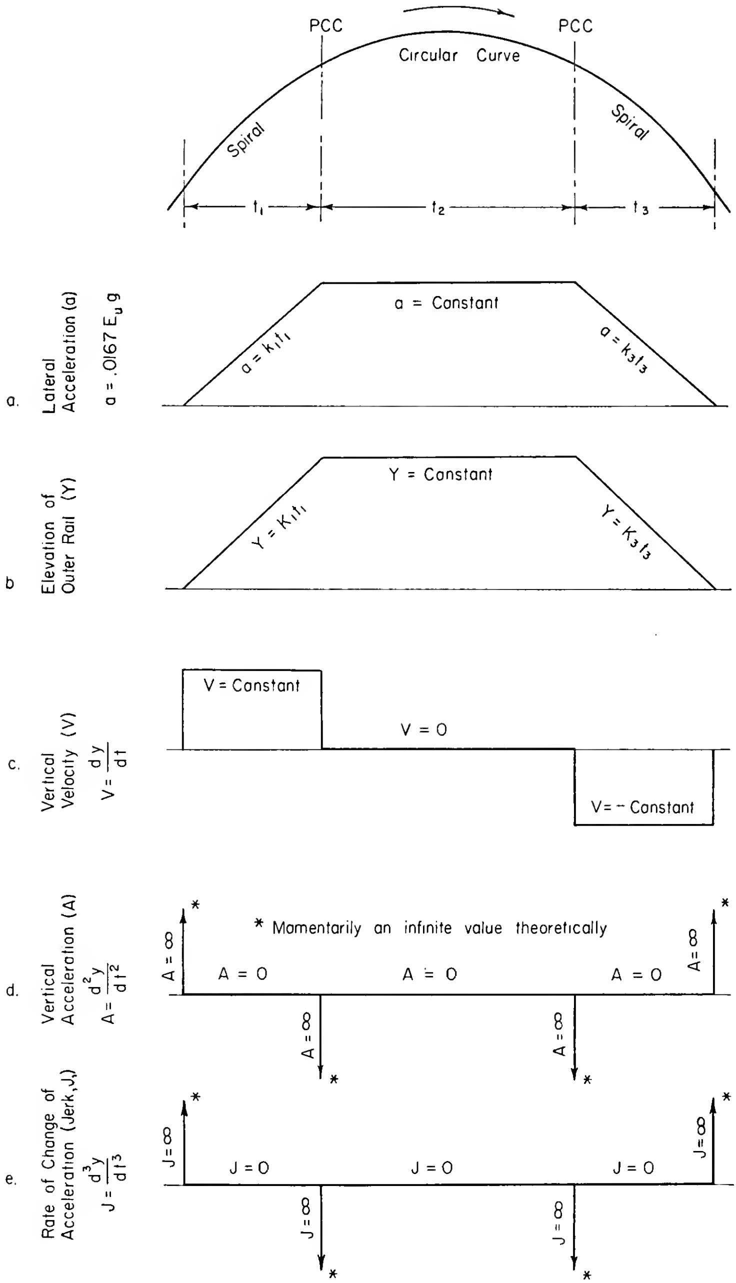


Fig. 7 - Diagrammatic Representation of Various Lateral and Vertical Quantities as a Car Traverses a Curve.

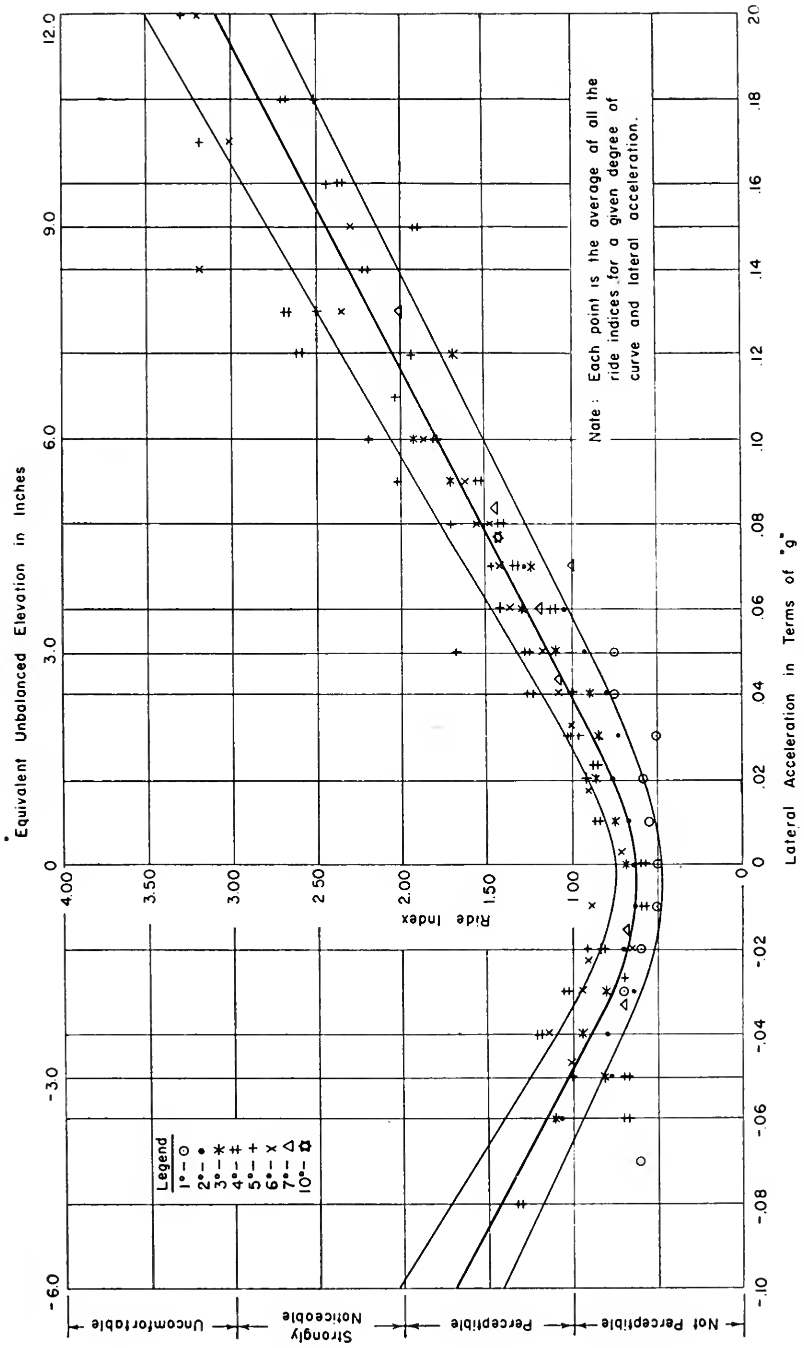


Fig. 8 Relation of Ride Index to Lateral Acceleration of Car Body – Average for L & N and KCS

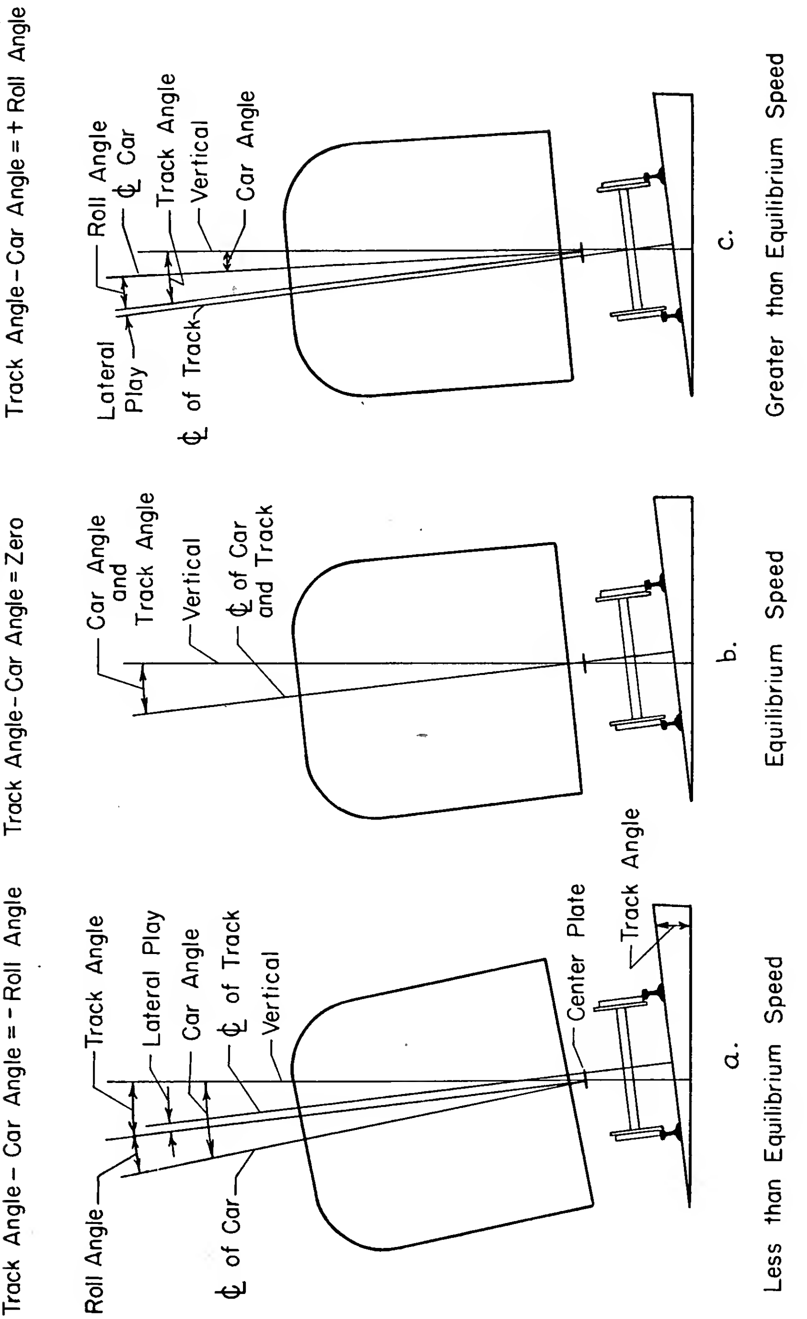
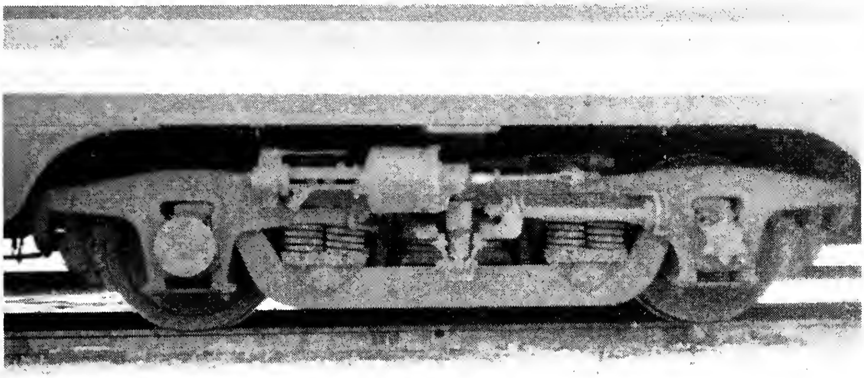
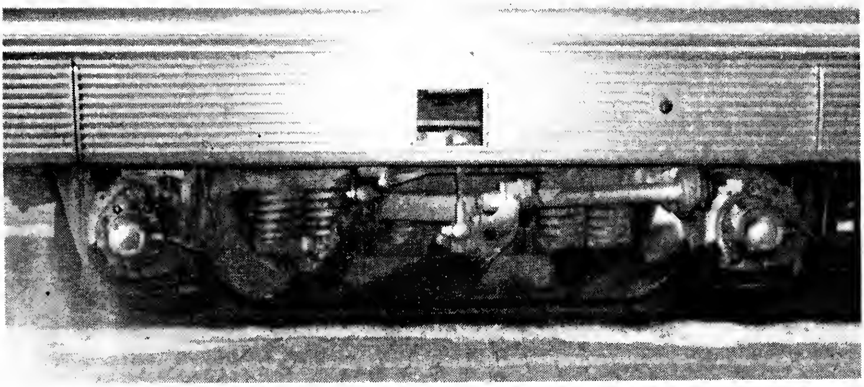


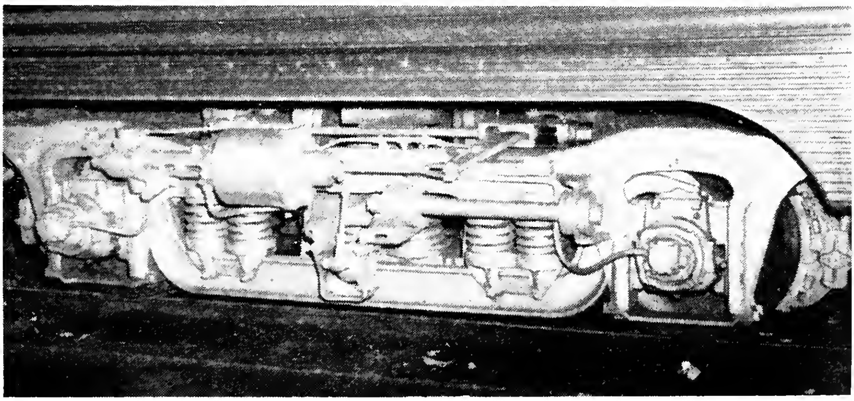
Fig. 9 Diagrammatic Representations of Car Body Position for Three Conditions



Kansas City Southern

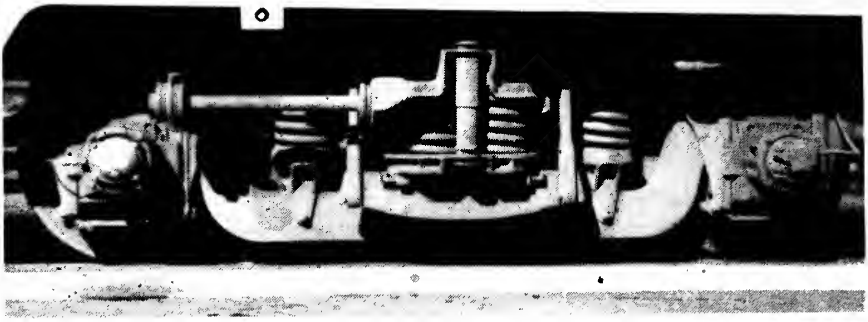


Burlington dome car—Roll stabilizer

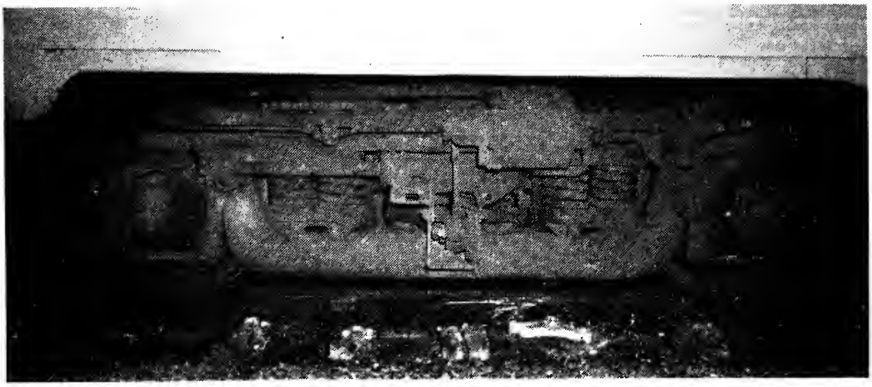


Santa Fe—Roll stabilizer

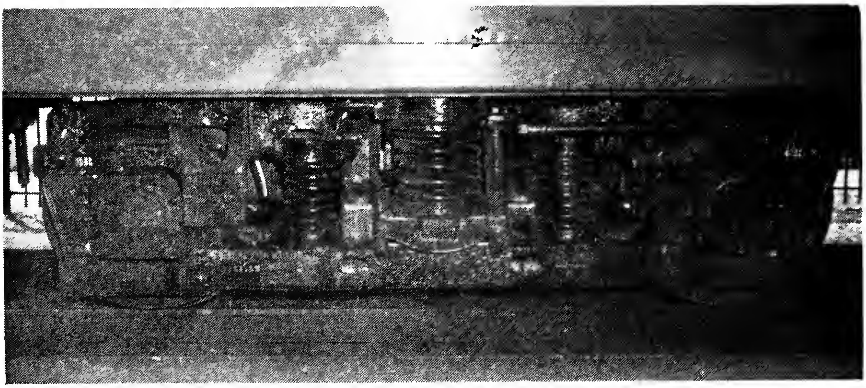
Fig. 10—Views of trucks on test cars.



Delaware, Lackawanna & Western—Outboard swing hangers

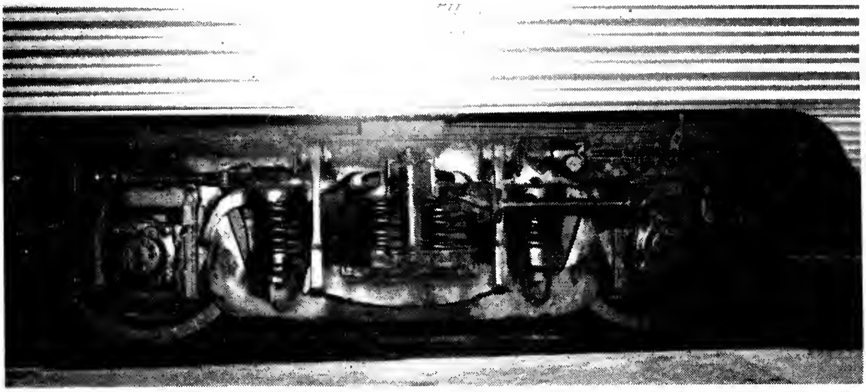


Delaware, Lackawanna & Western—Inboard swing hangers

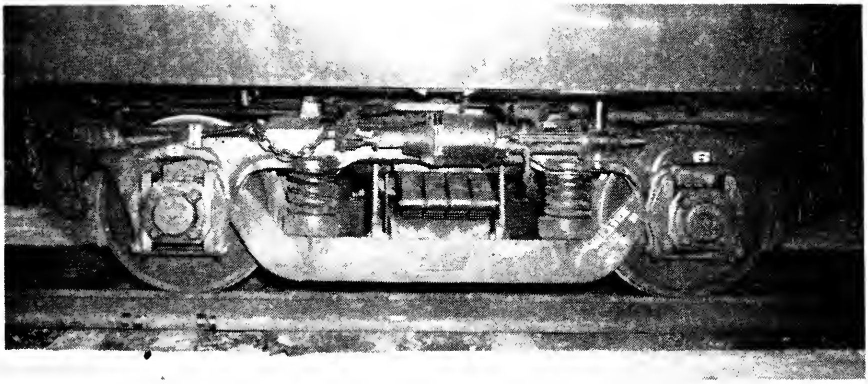


Milwaukee—No swing hangers

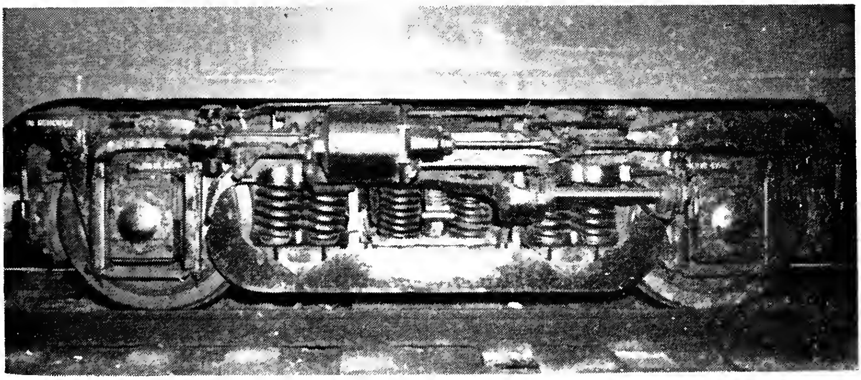
Fig. 11—Views of trucks on test cars.



New Haven—Outboard swing hangers



New Haven—Inboard swing hangers



Pennsylvania—Leaf spring

Fig. 12—Views of trucks on test cars.

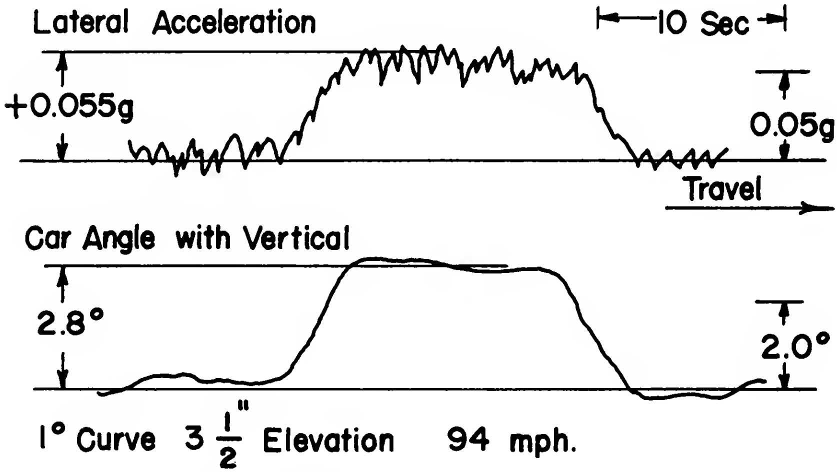


Fig. 13 Typical Acceleration and Inclination Records.

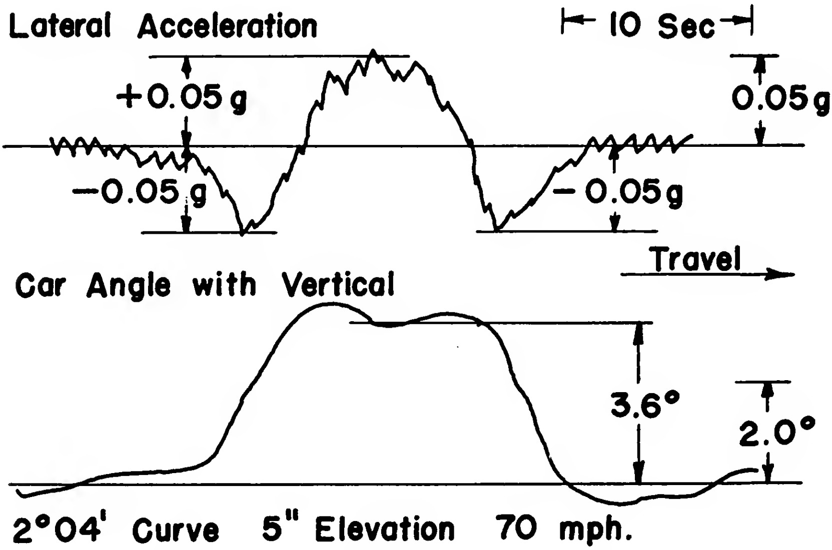


Fig. 14 Tracing of Records Showing Reverse Acceleration at Entrance to Curve.

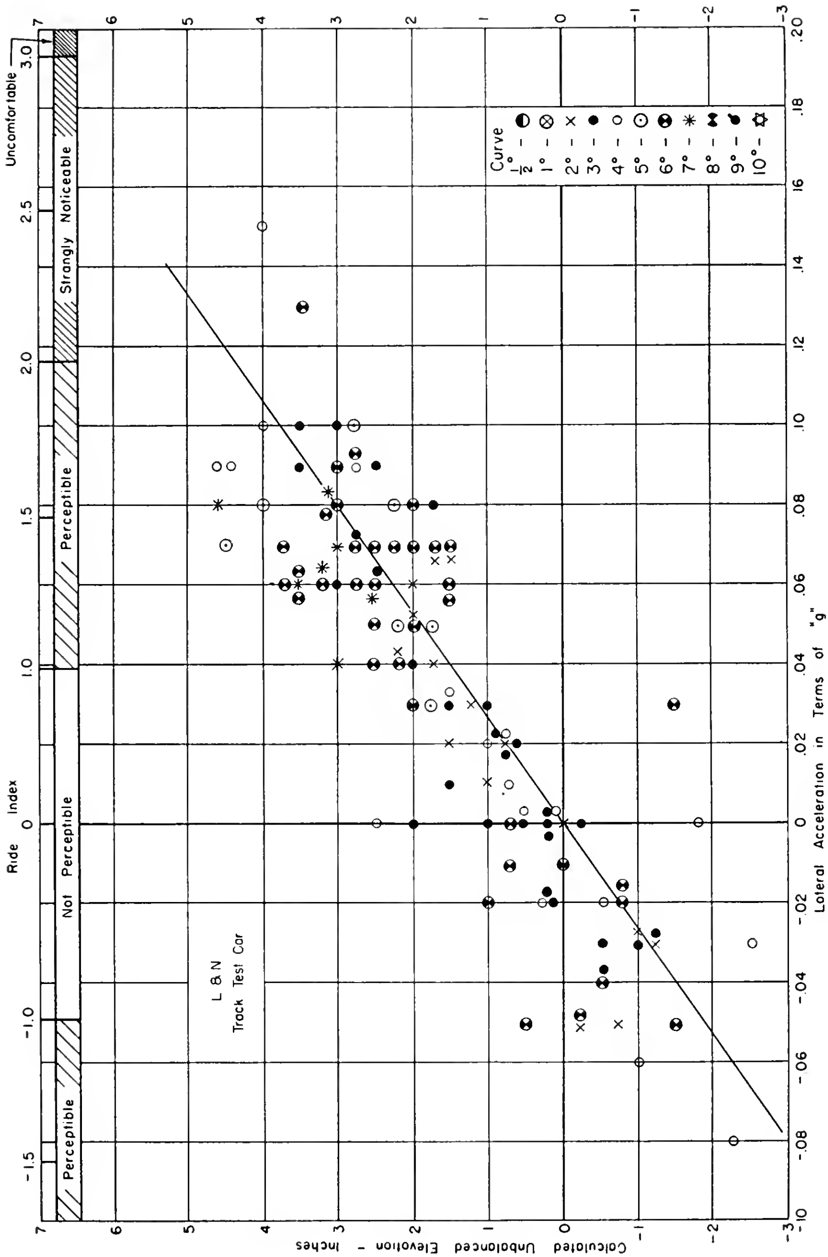


Fig 15 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves.

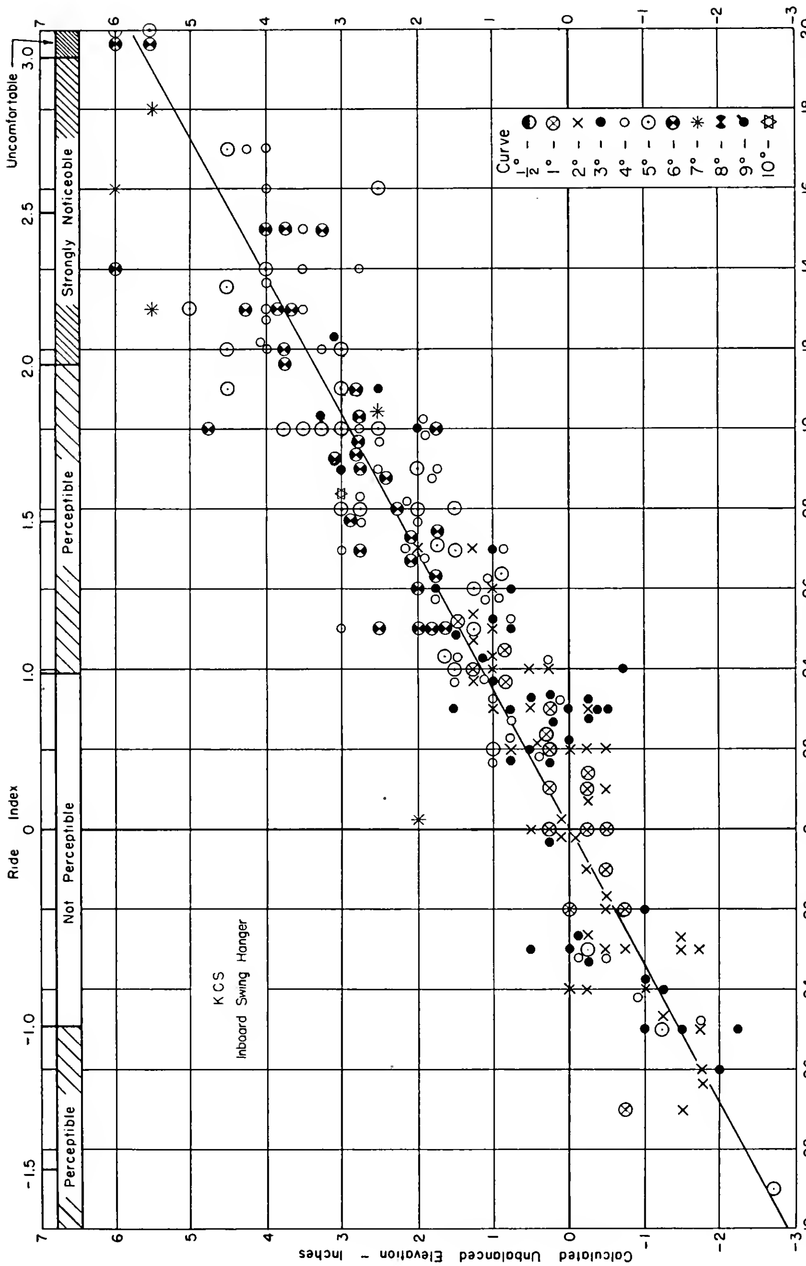


Fig. 16 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves.

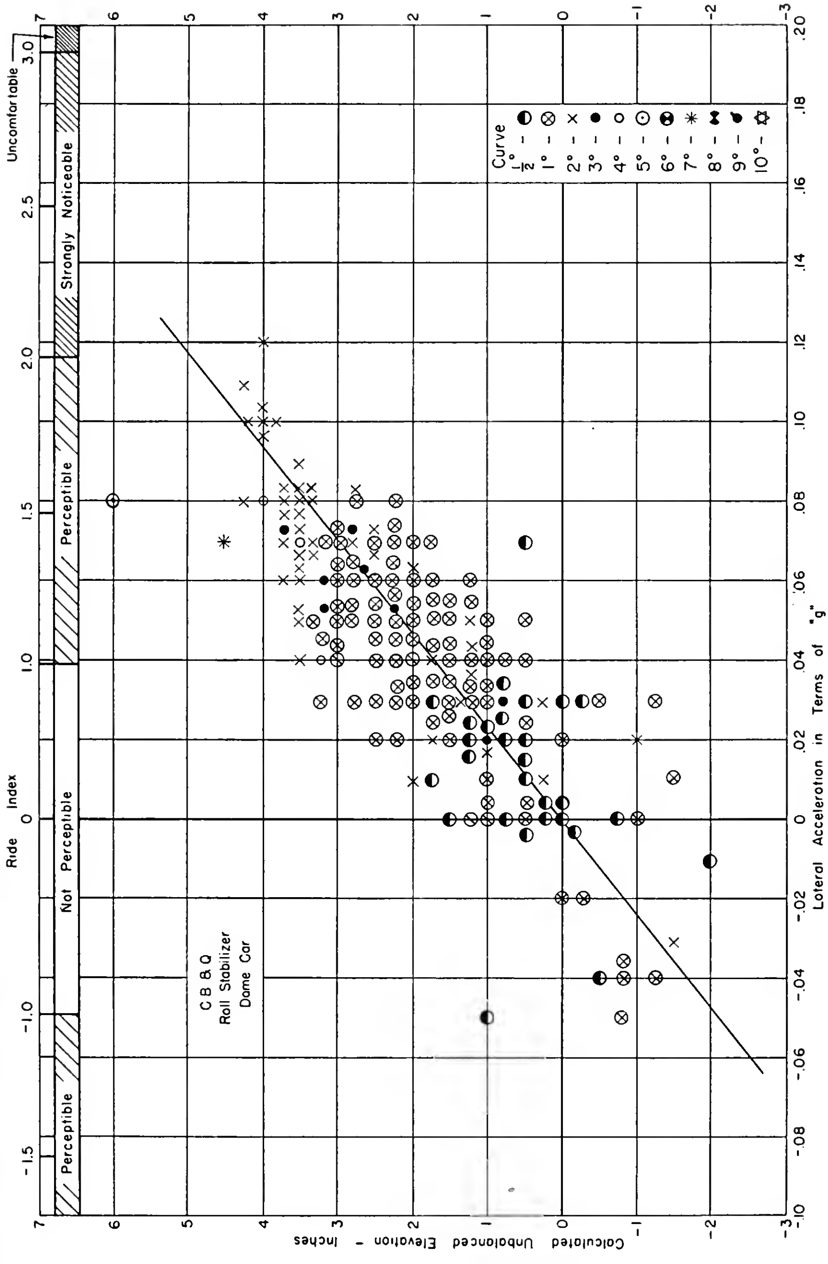


Fig 17 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves

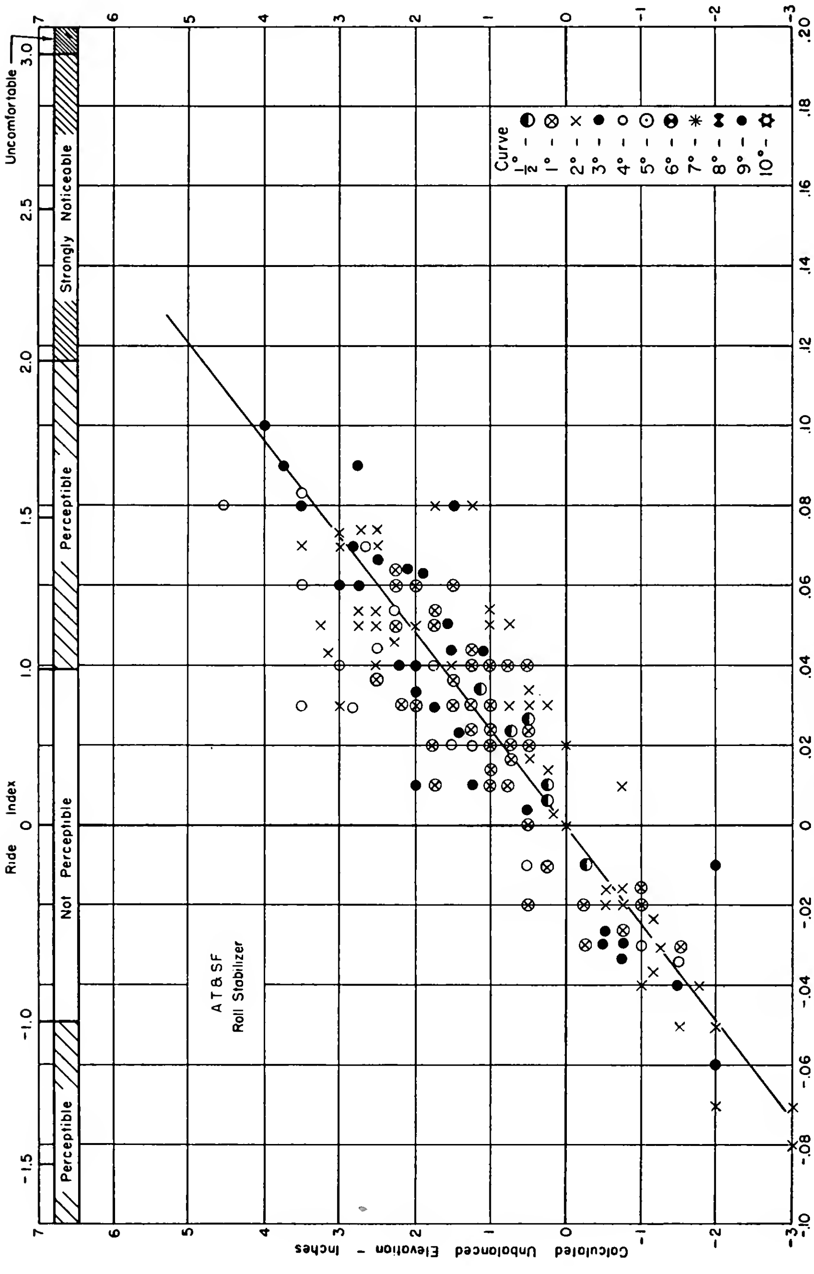


Fig.18 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves

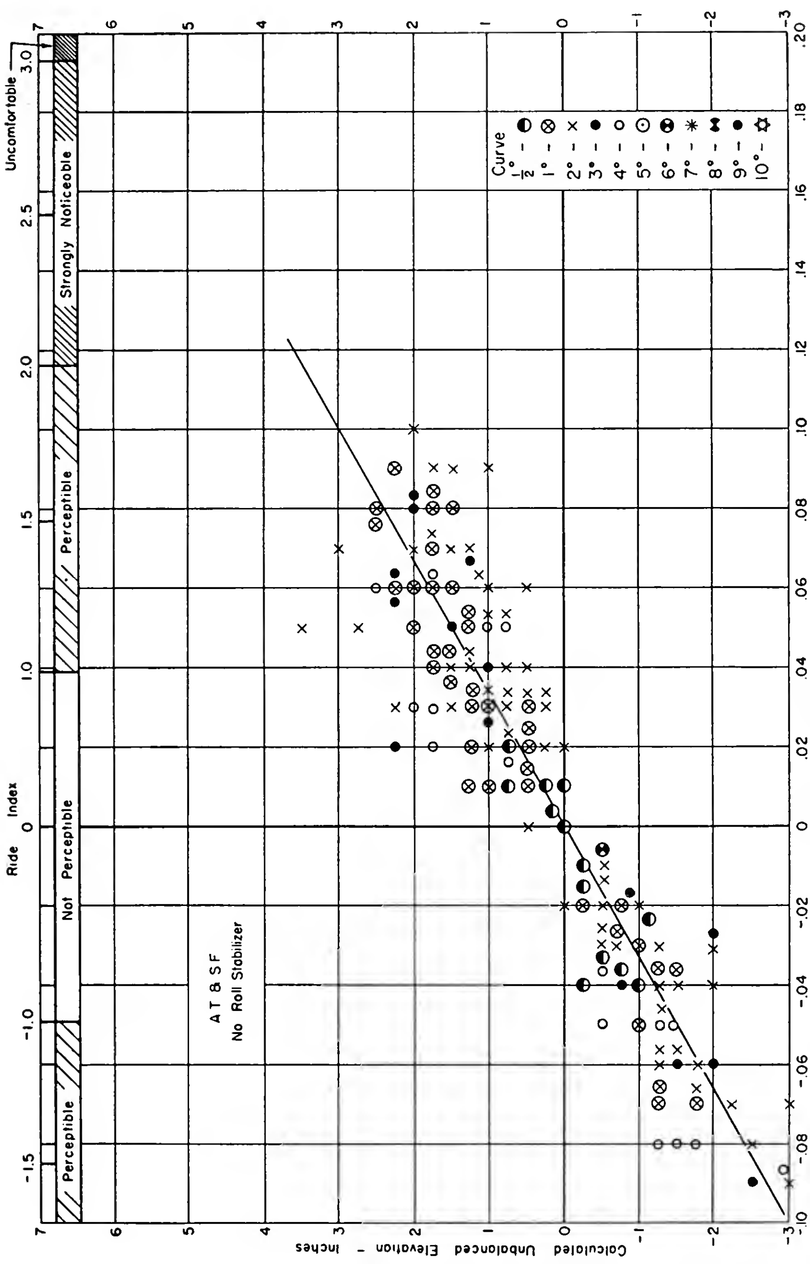


Fig. 19 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves

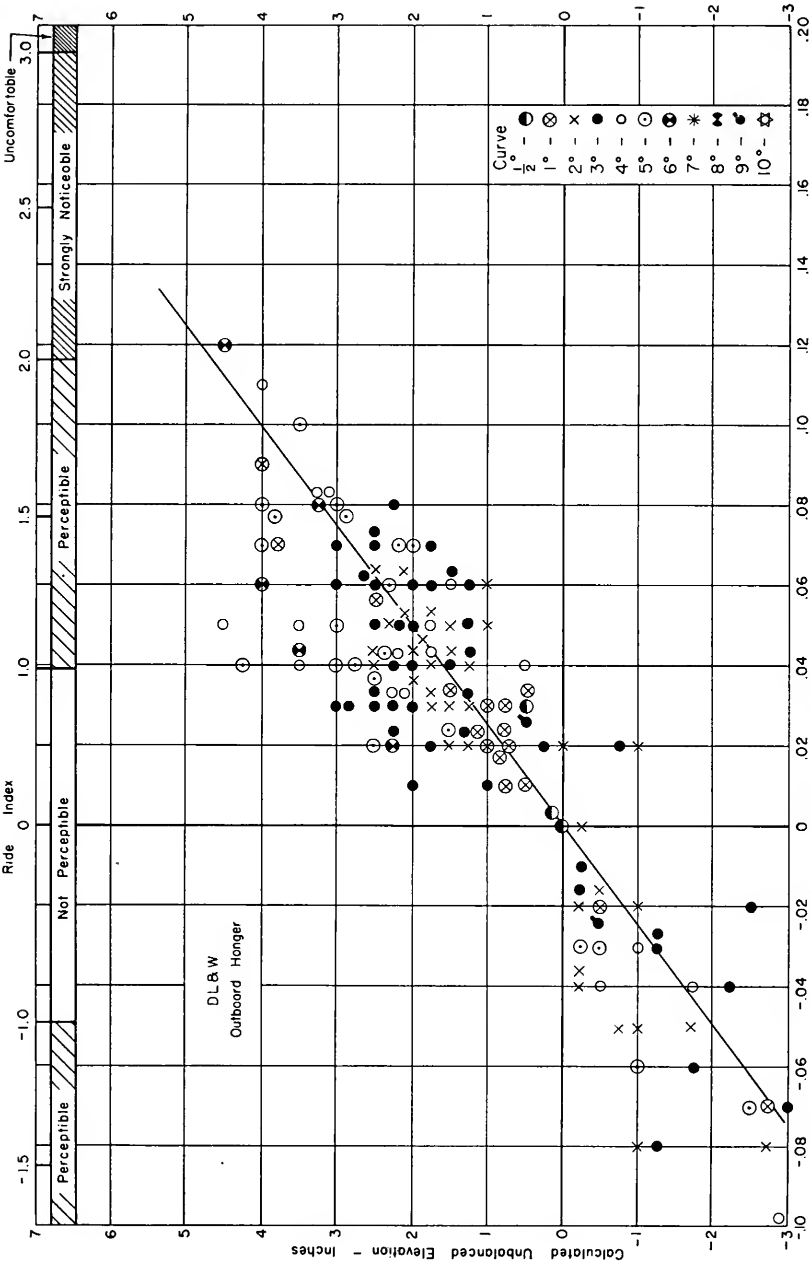


Fig. 20 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves.

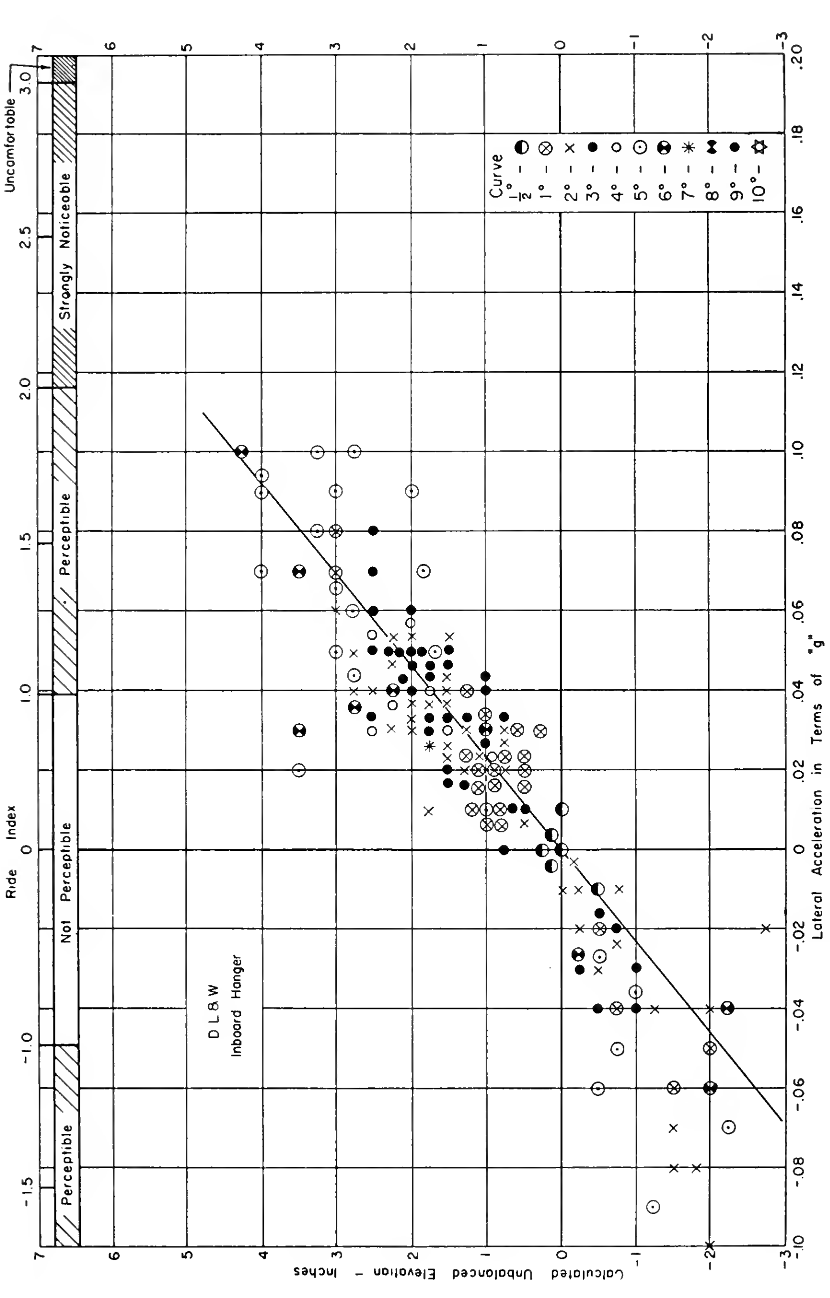


Fig. 21 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves.

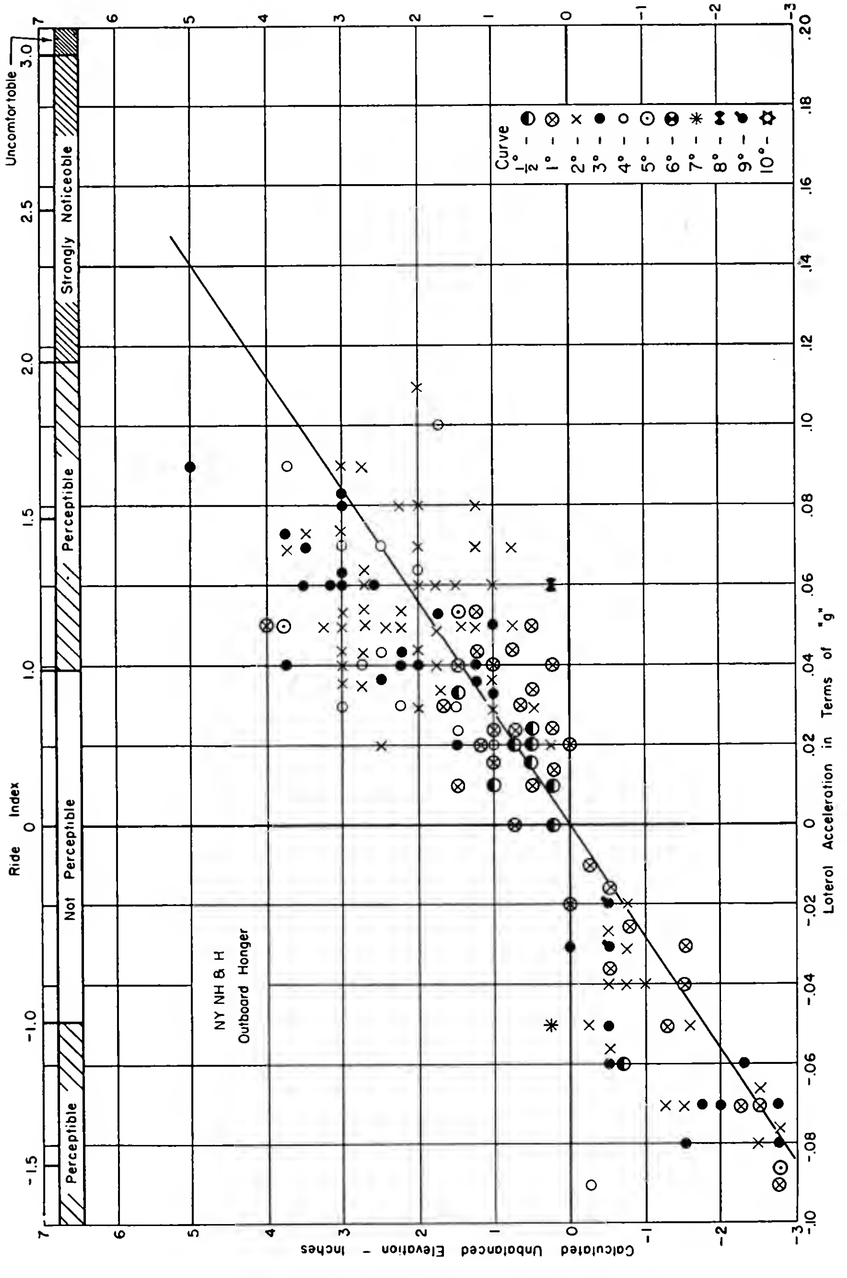


Fig 22 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves

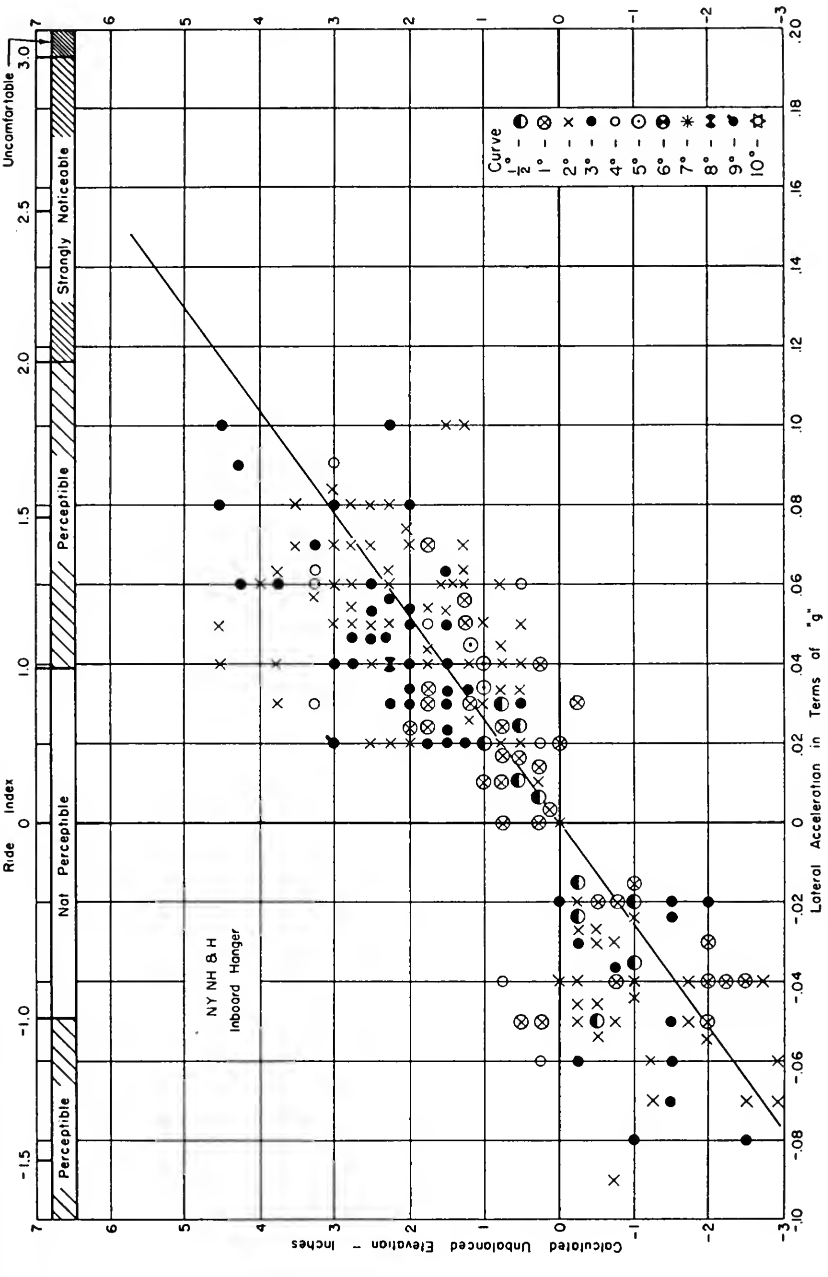


Fig. 23 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves.

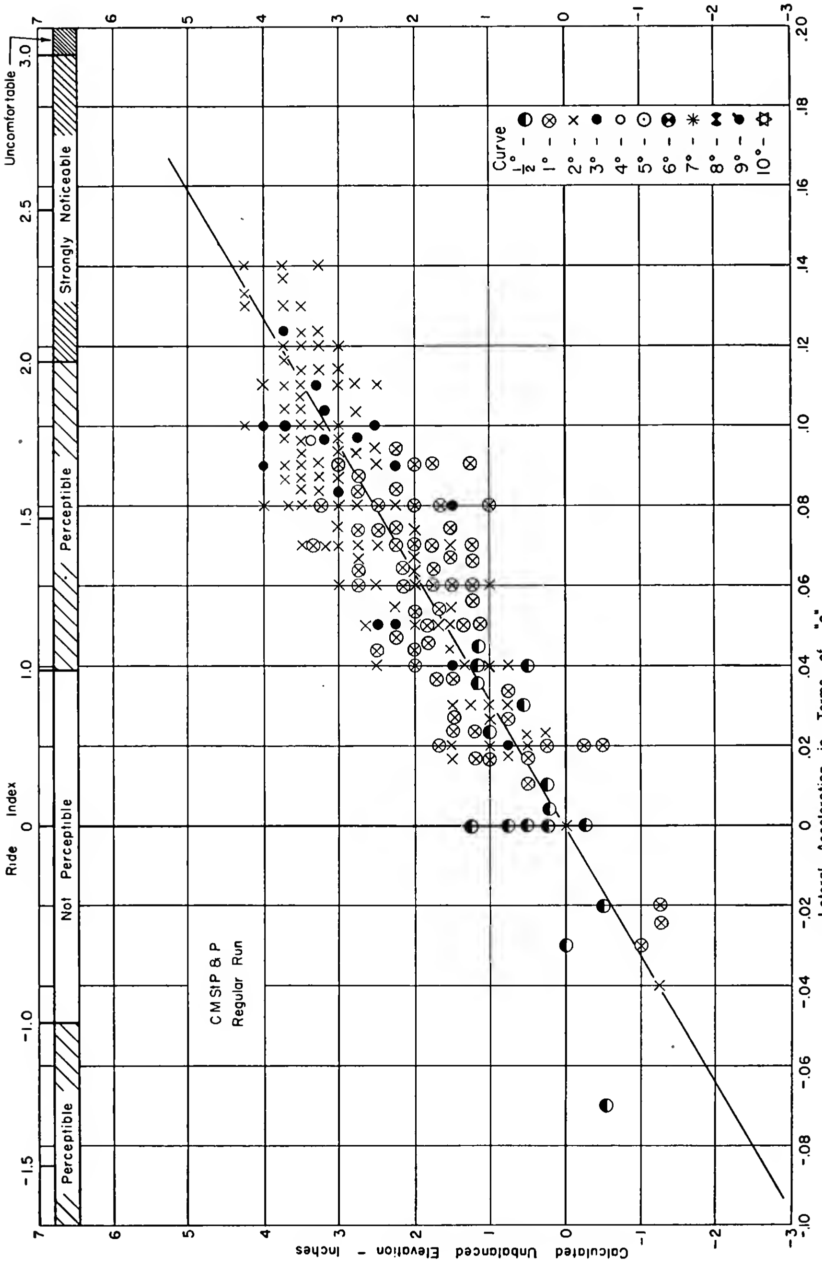


Fig. 24 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves.

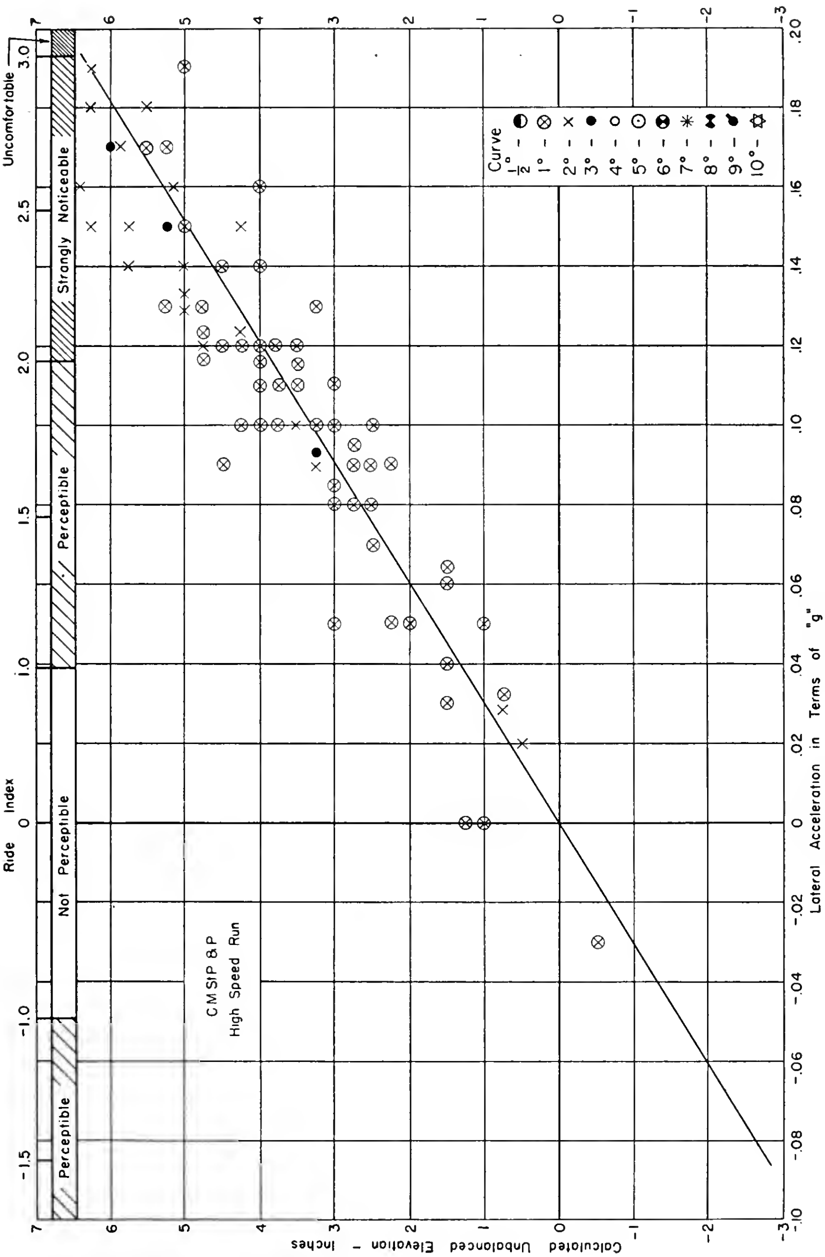


Fig. 25 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves.

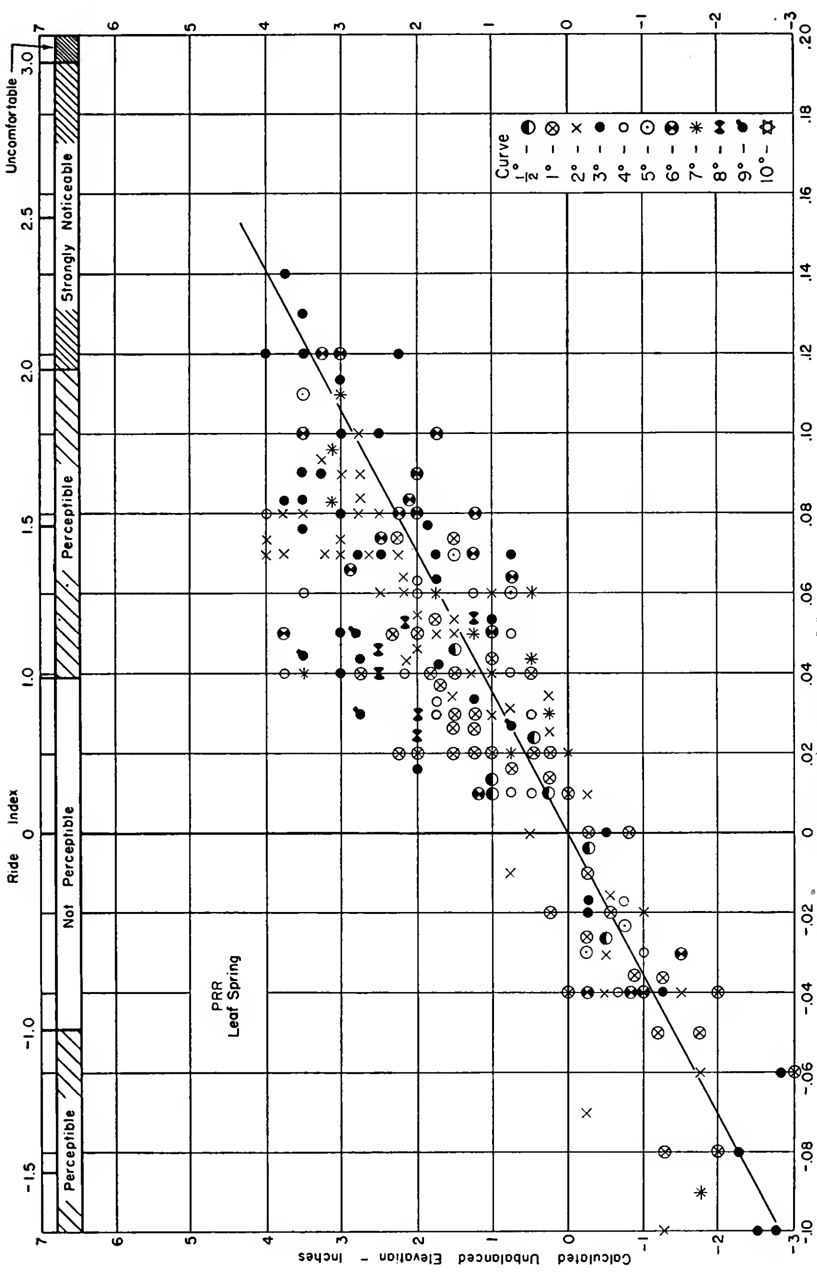


Fig.26 - Relation of Lateral Acceleration and Ride Index to Calculated Unbalanced Elevation on Curves.

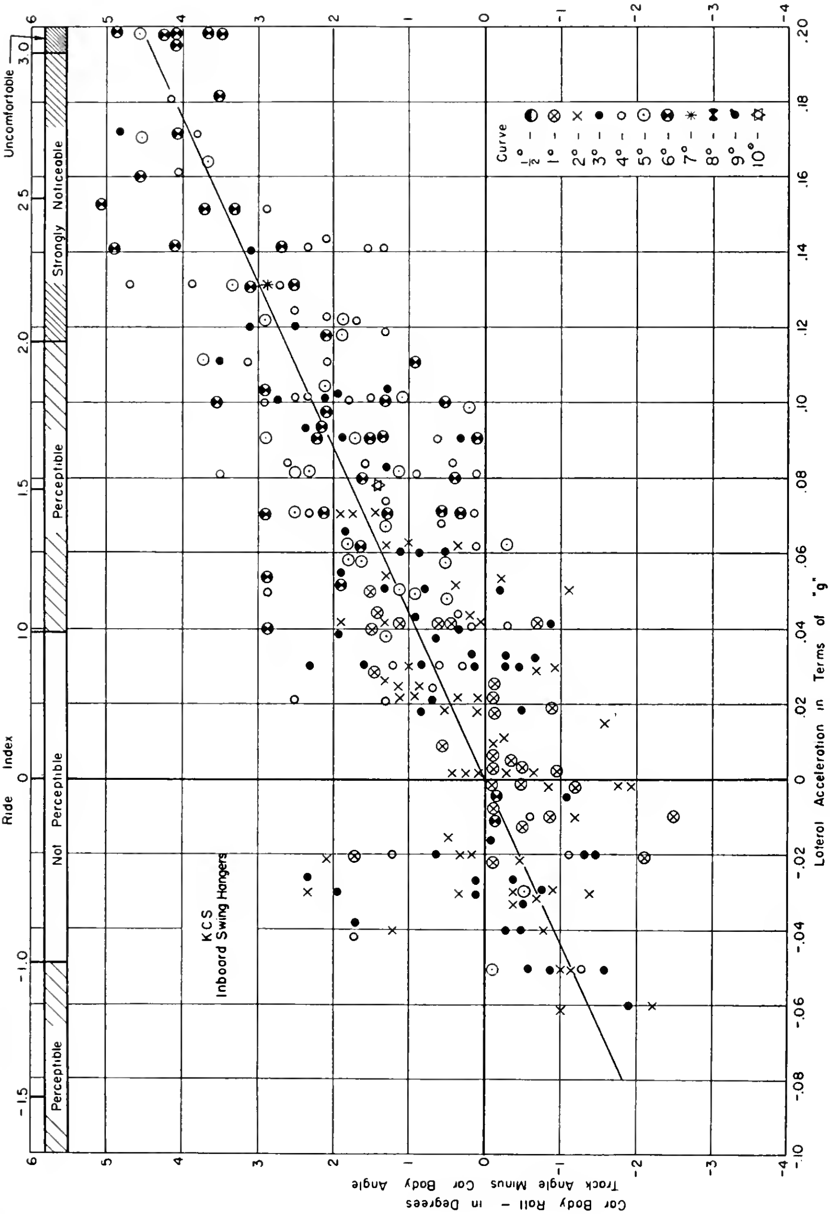


Fig. 27 - Car Body Roll and Lateral Acceleration

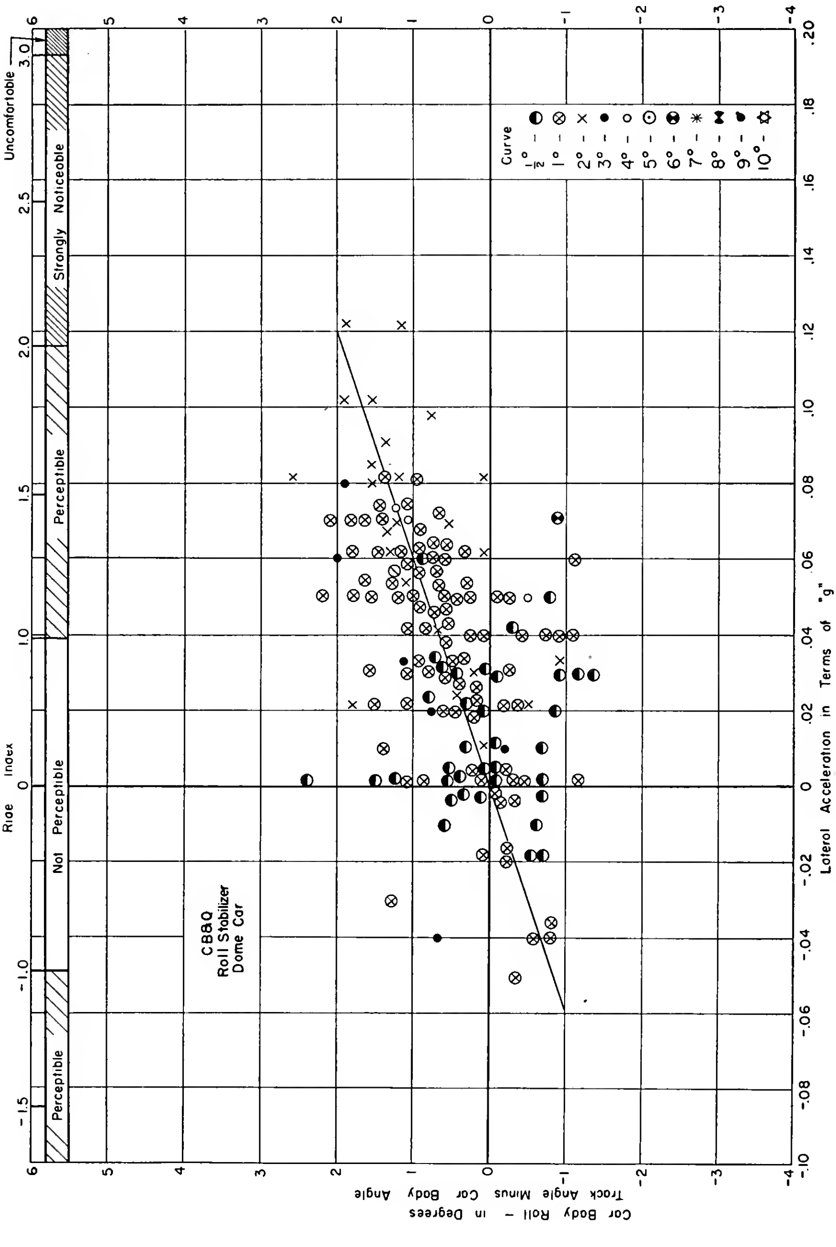


Fig. 28 - Car Body Roll and Lateral Acceleration

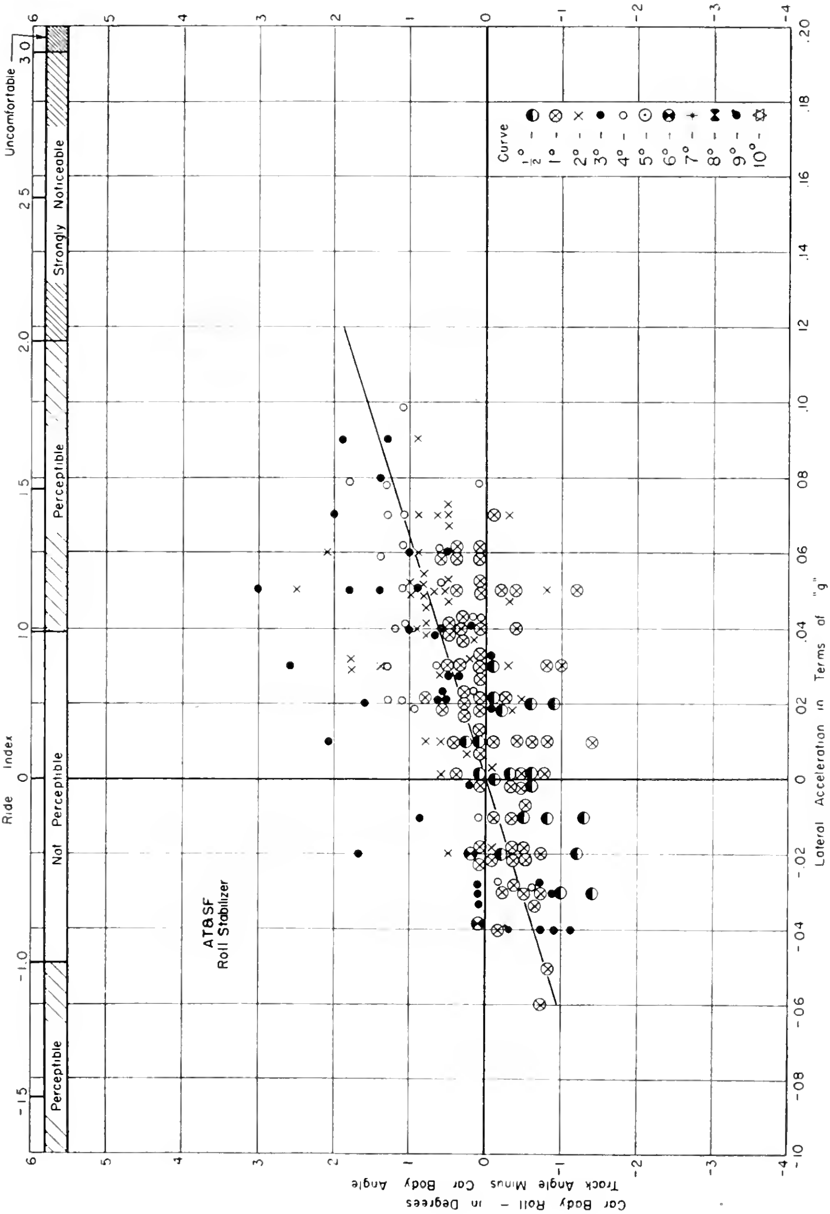


Fig 29 - Car Body Roll and Lateral Acceleration

A

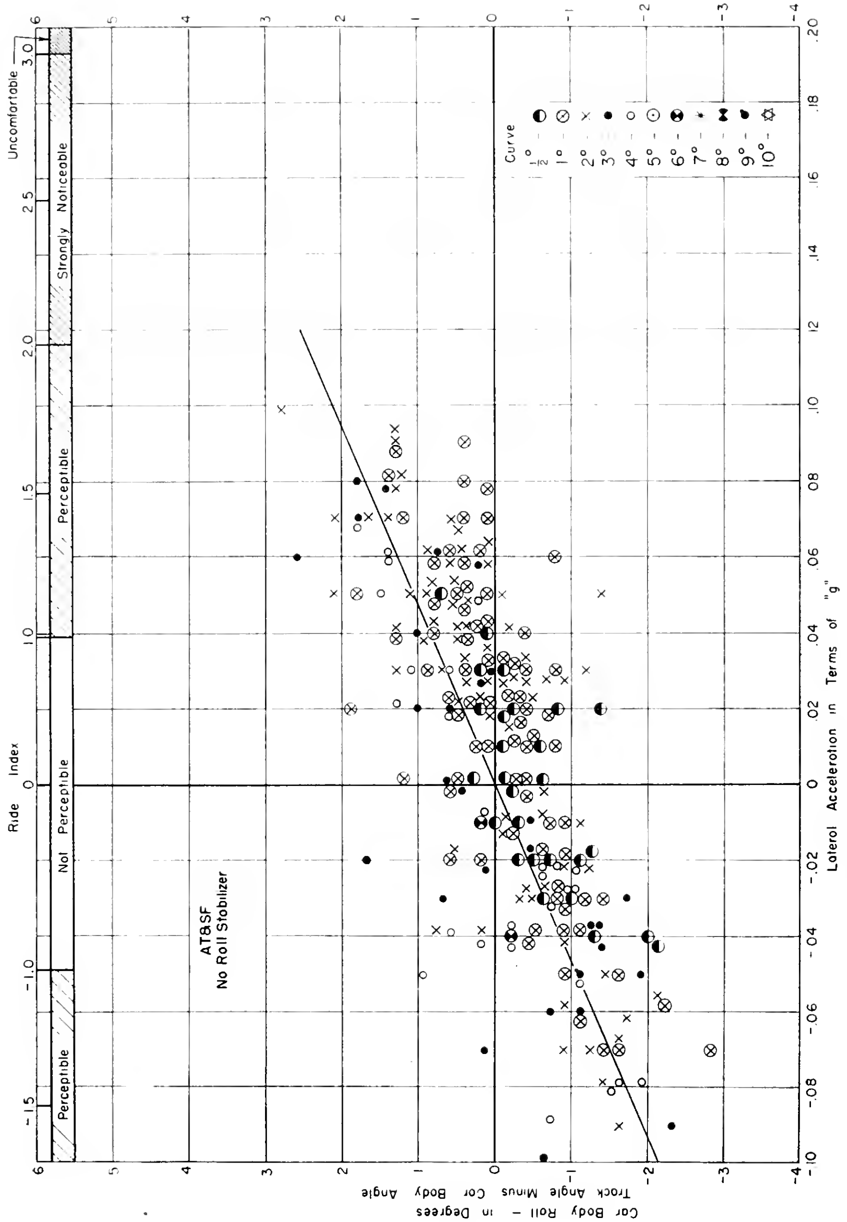


Fig. 30 - Car Body Roll and Lateral Acceleration

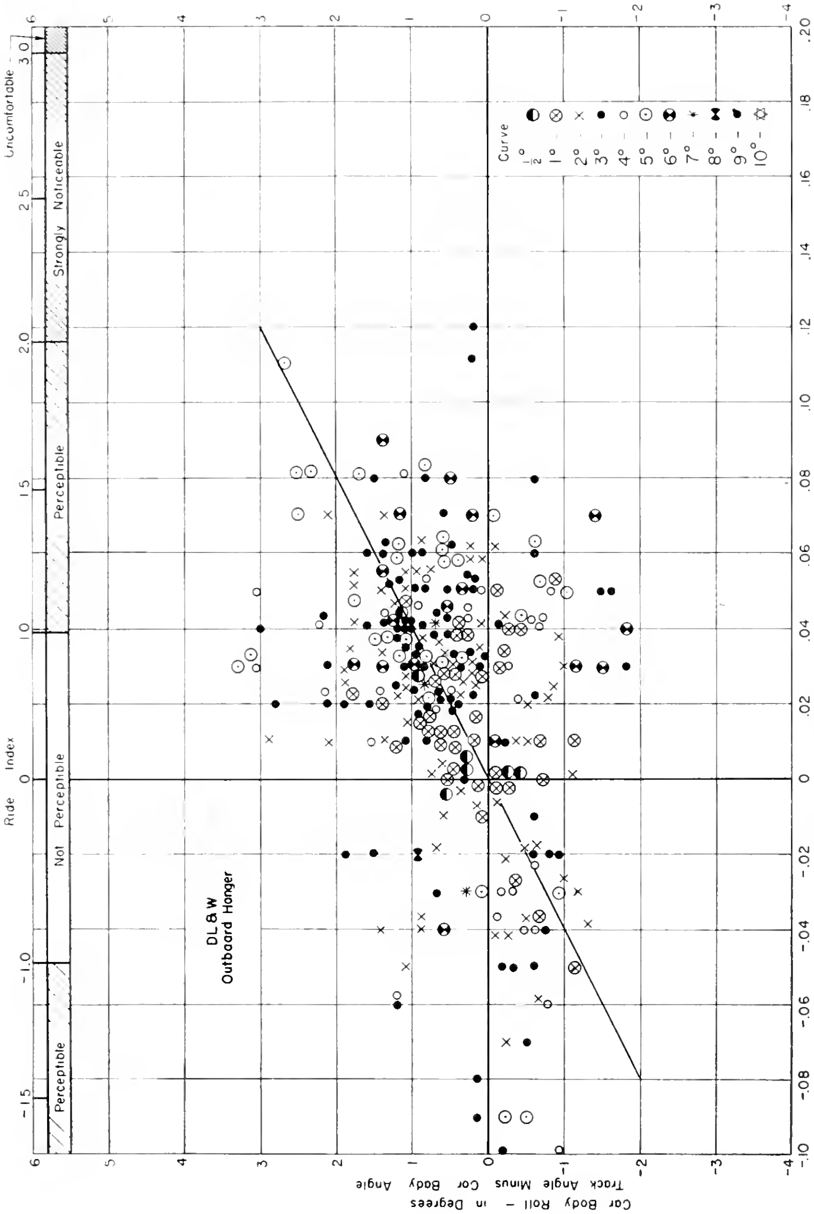


Fig 31 - Car Body Roll and Lateral Acceleration

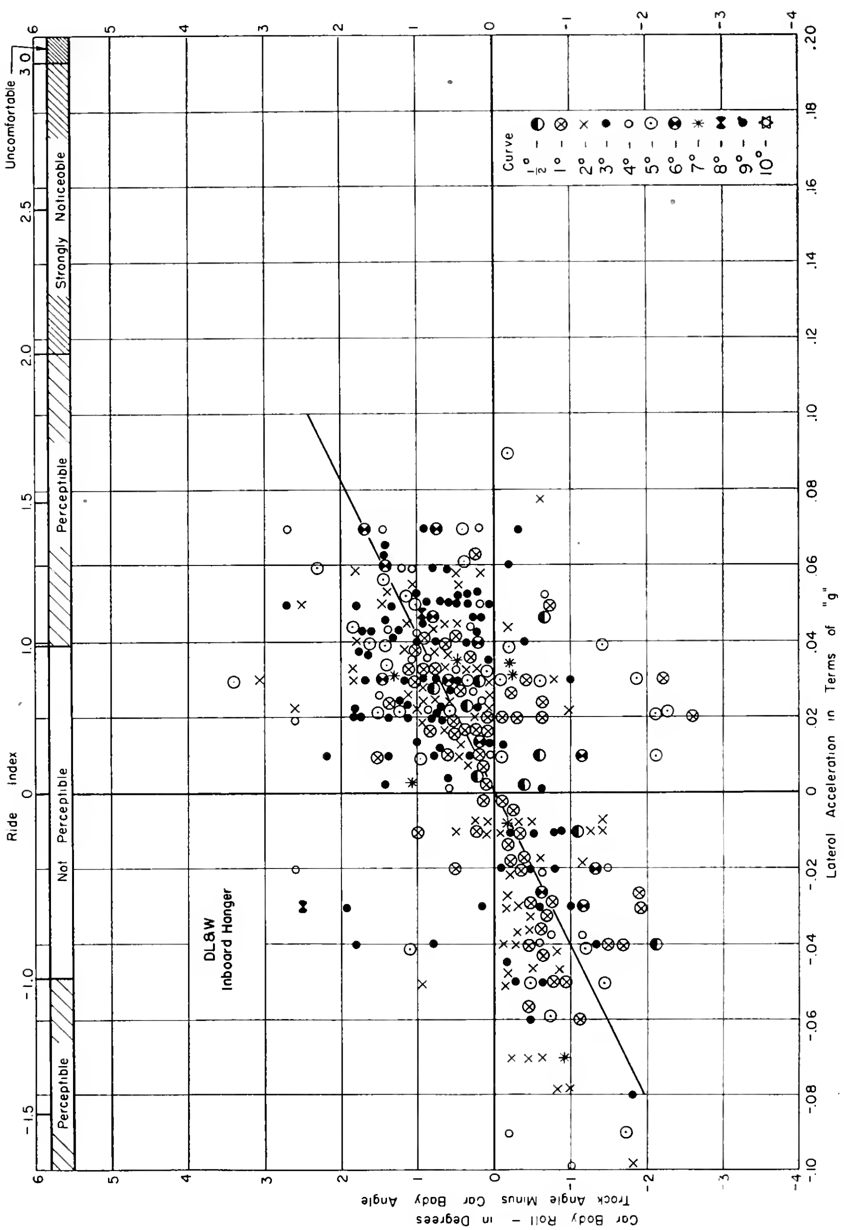


Fig 32 - Car Body Roll and Lateral Acceleration

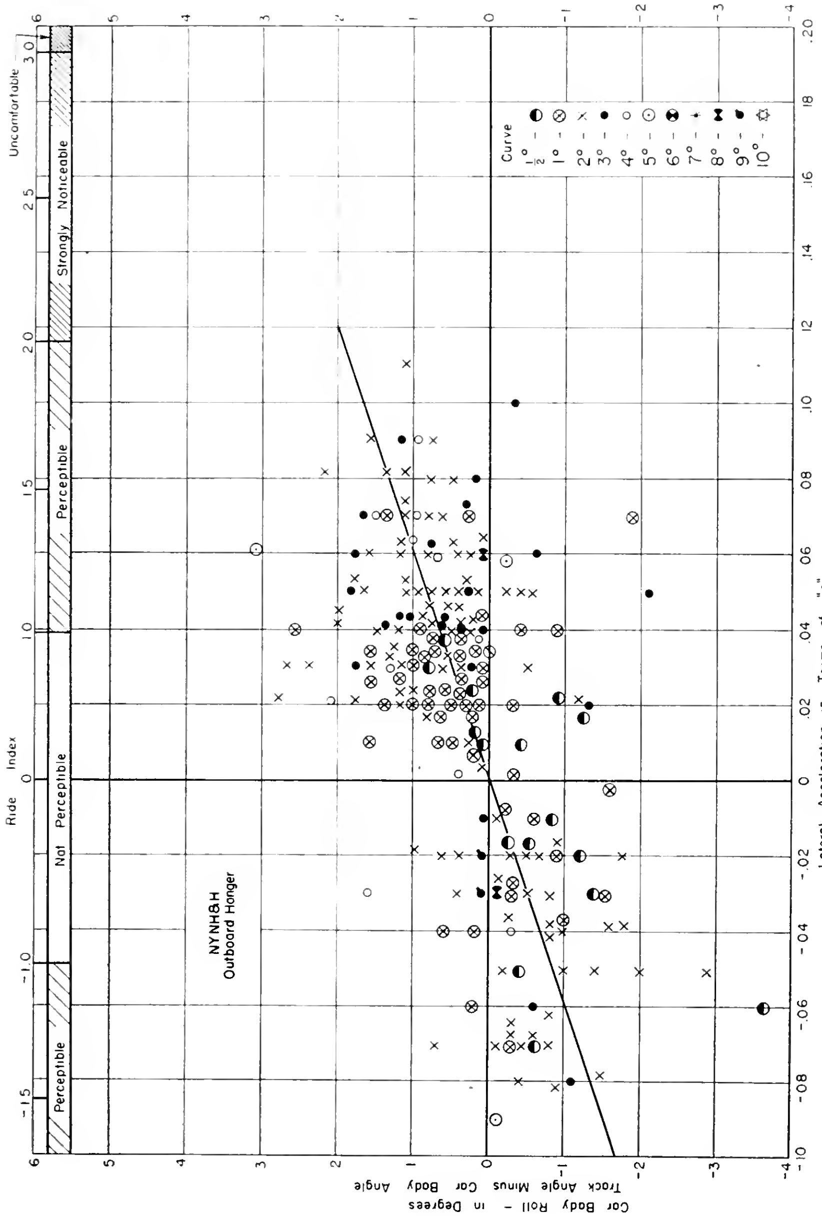


Fig 33 - Car Body Roll and Lateral Acceleration

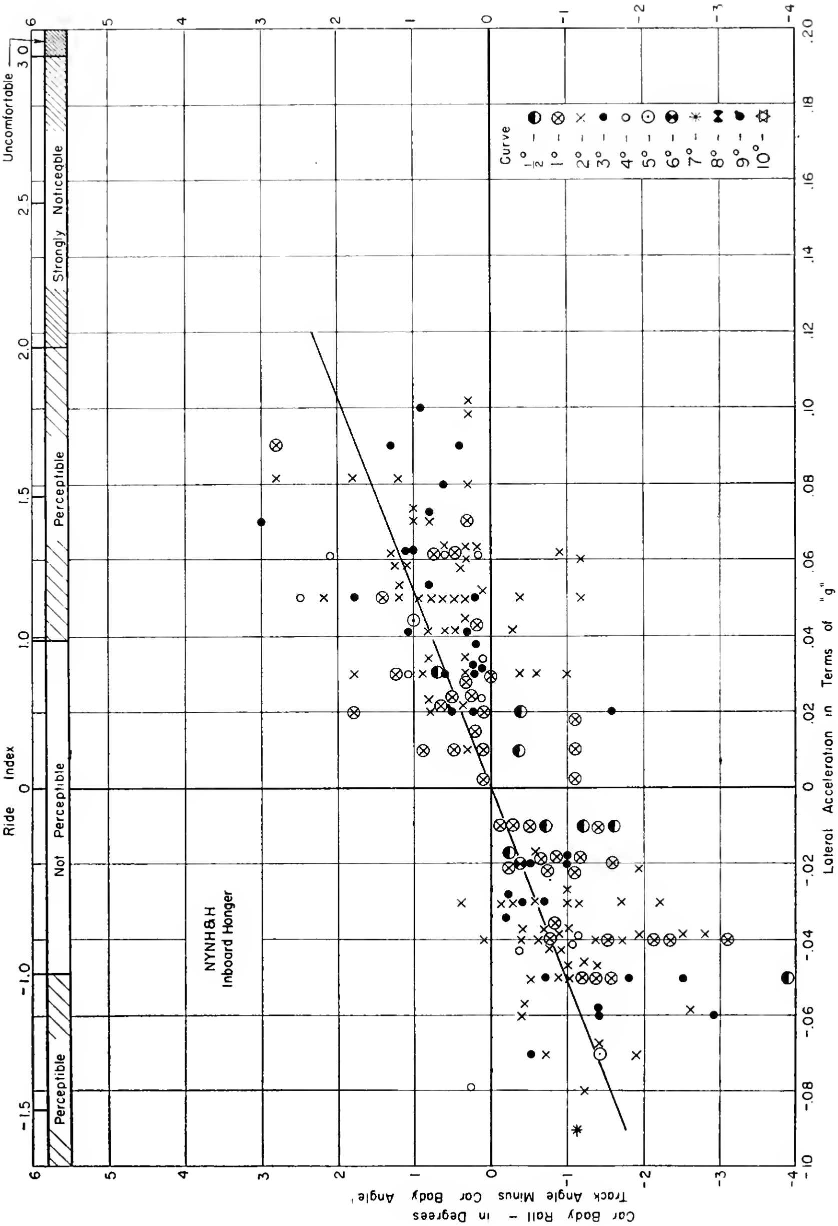


Fig 34 - Car Body Roll and Lateral Acceleration

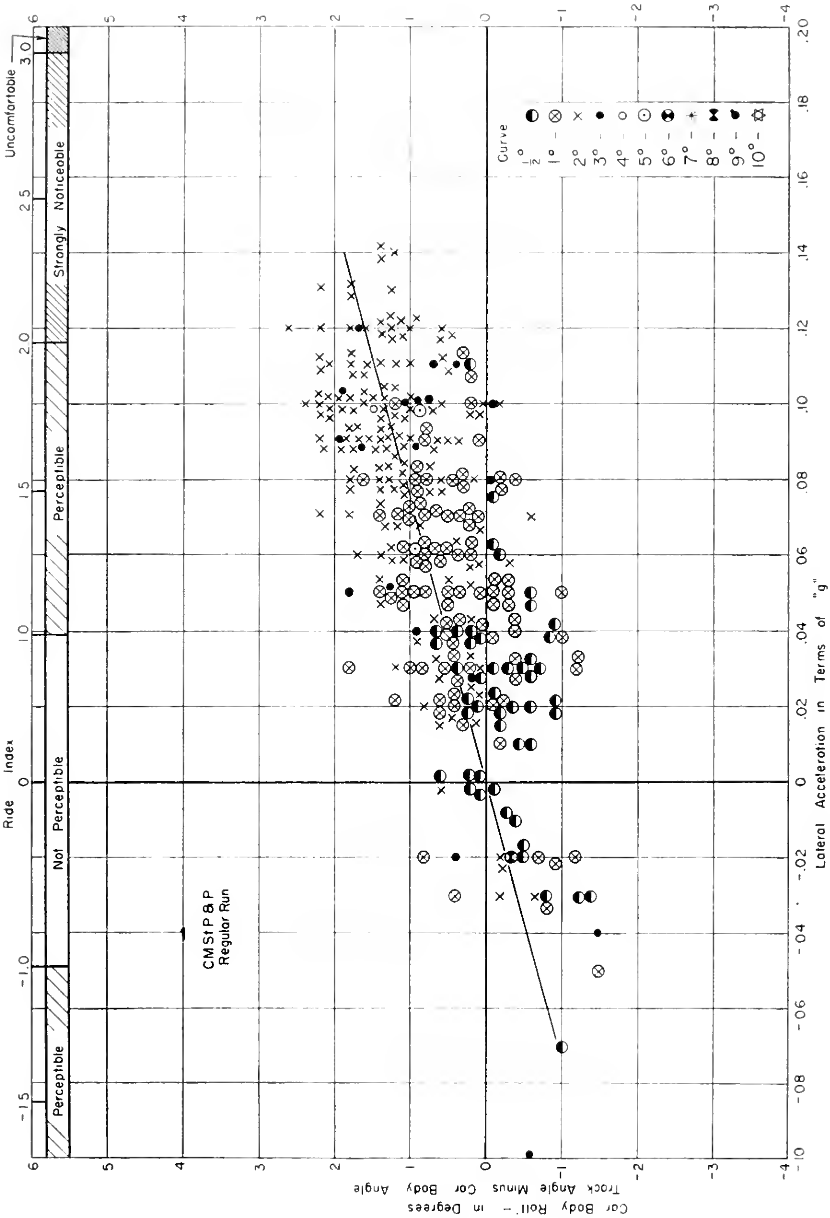


Fig 35 - Car Body Roll and Lateral Acceleration

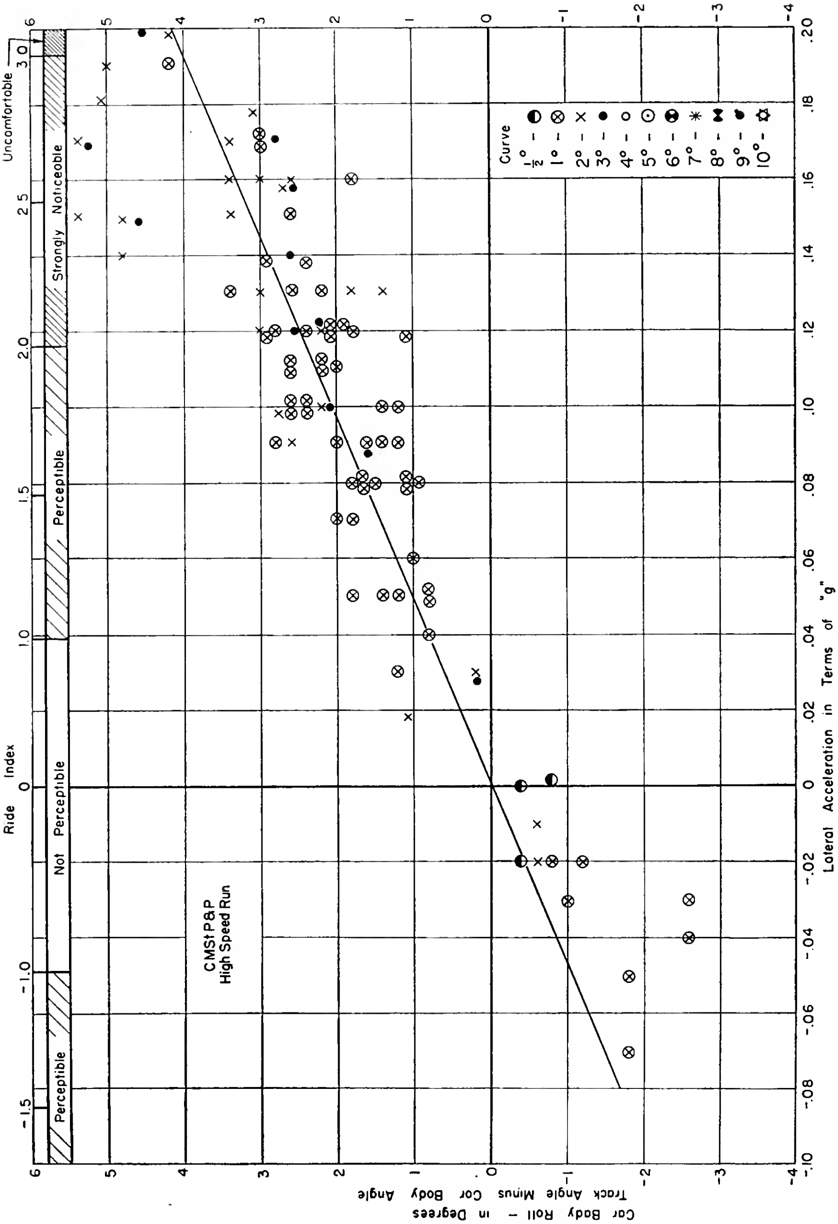


Fig. 36 - Car Body Roll and Lateral Acceleration

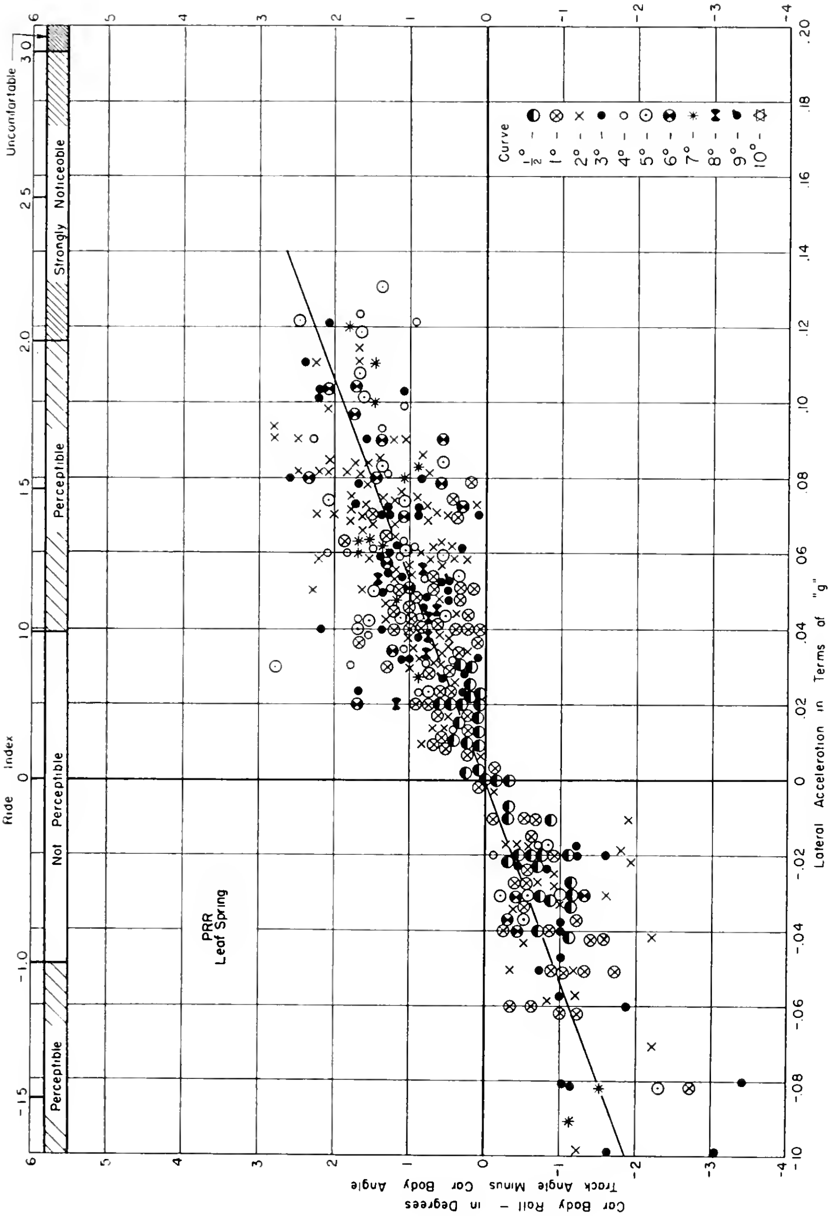


Fig 37 - Car Body Roll and Lateral Acceleration

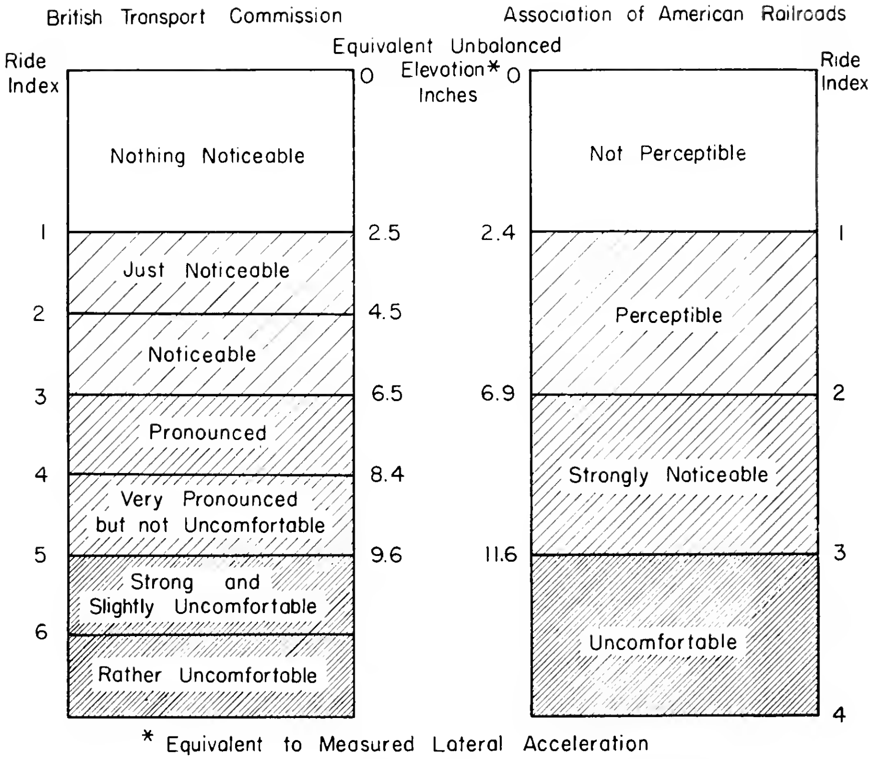


Fig. 38 - Correlation of Sensation Levels in A A R and British Ride Comfort Tests.

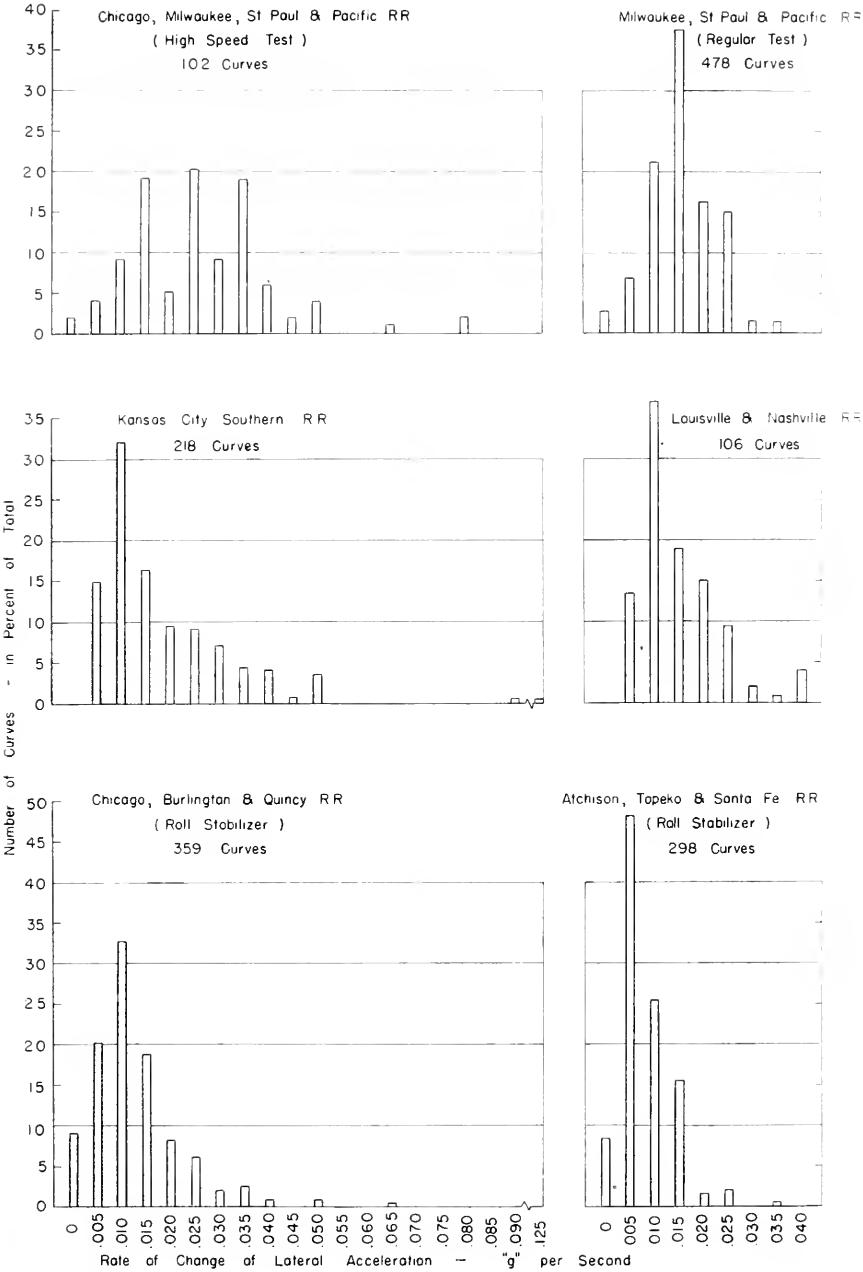


Fig 39 - Rate of Change of Acceleration in Spiral Transition Curves on Several Railroads

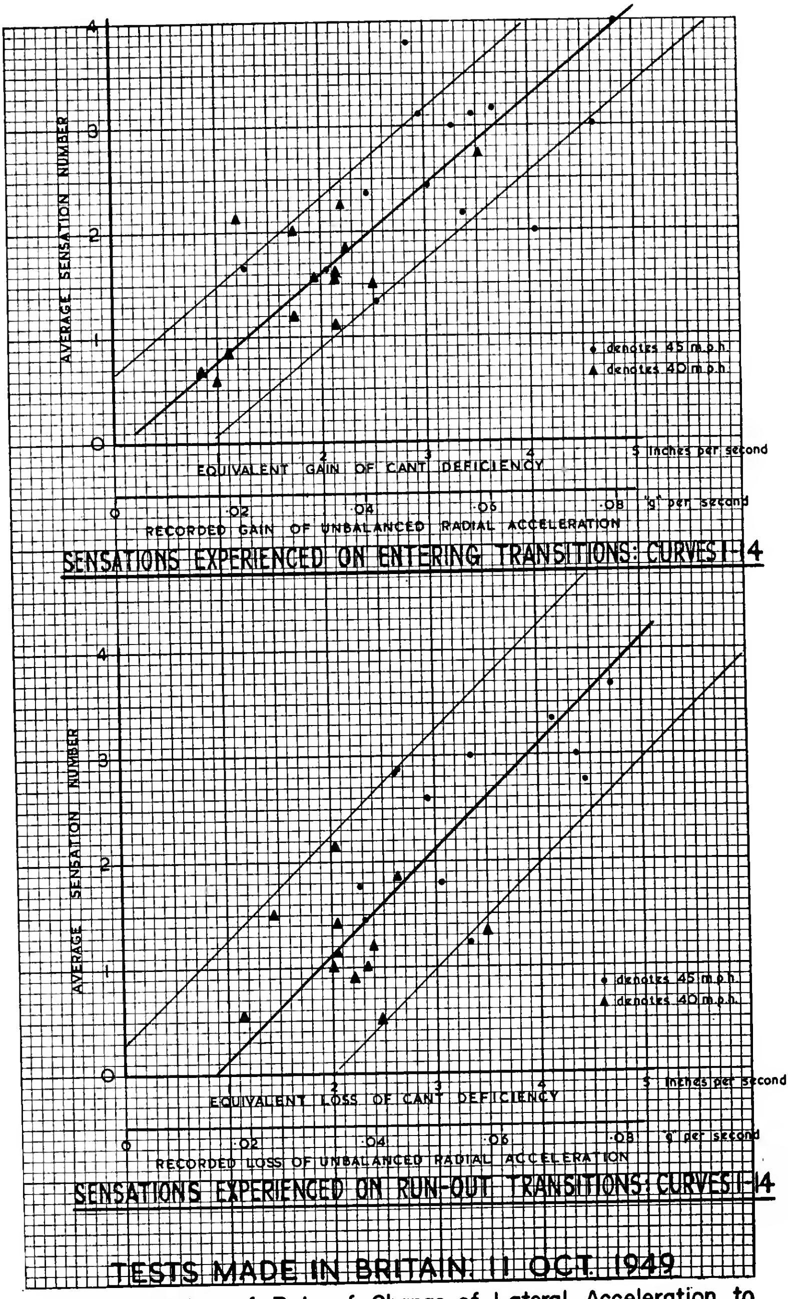


Fig. 40 Relation of Rate of Change of Lateral Acceleration to Ride Comfort — Loach and Maycock. (7)

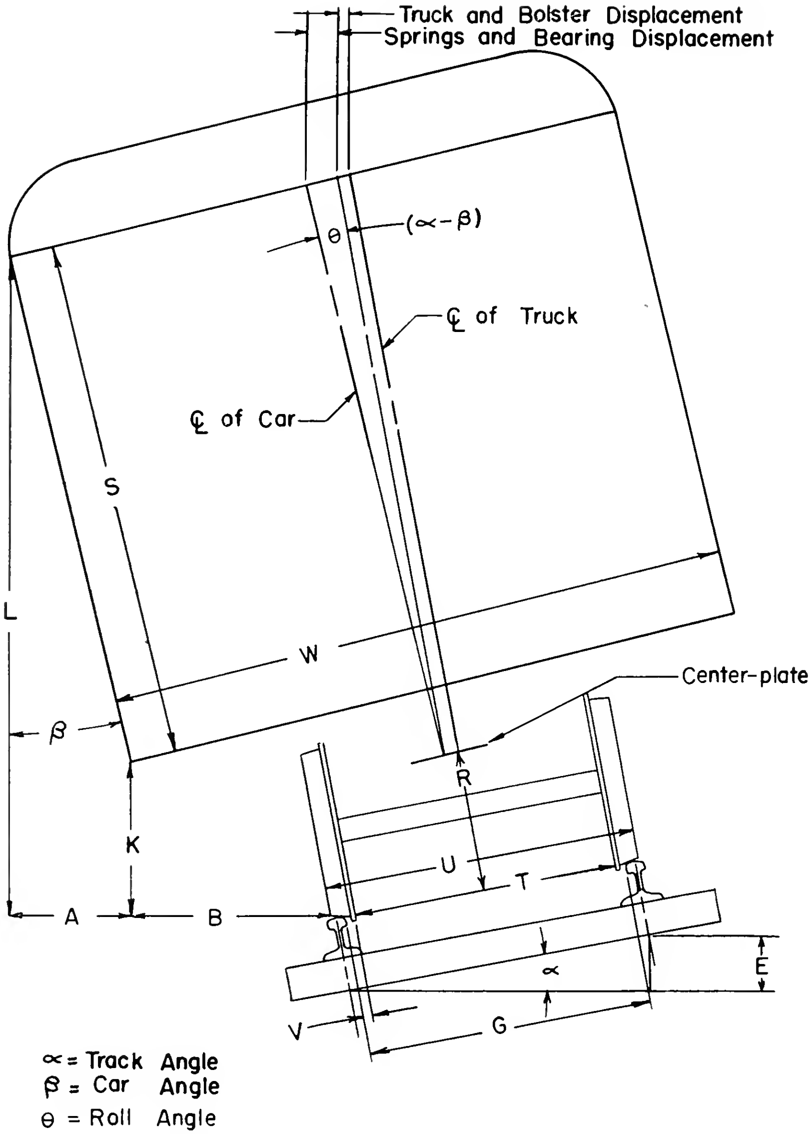


Fig. 41 Diagram of Measurements on Passenger Car Lean Test.

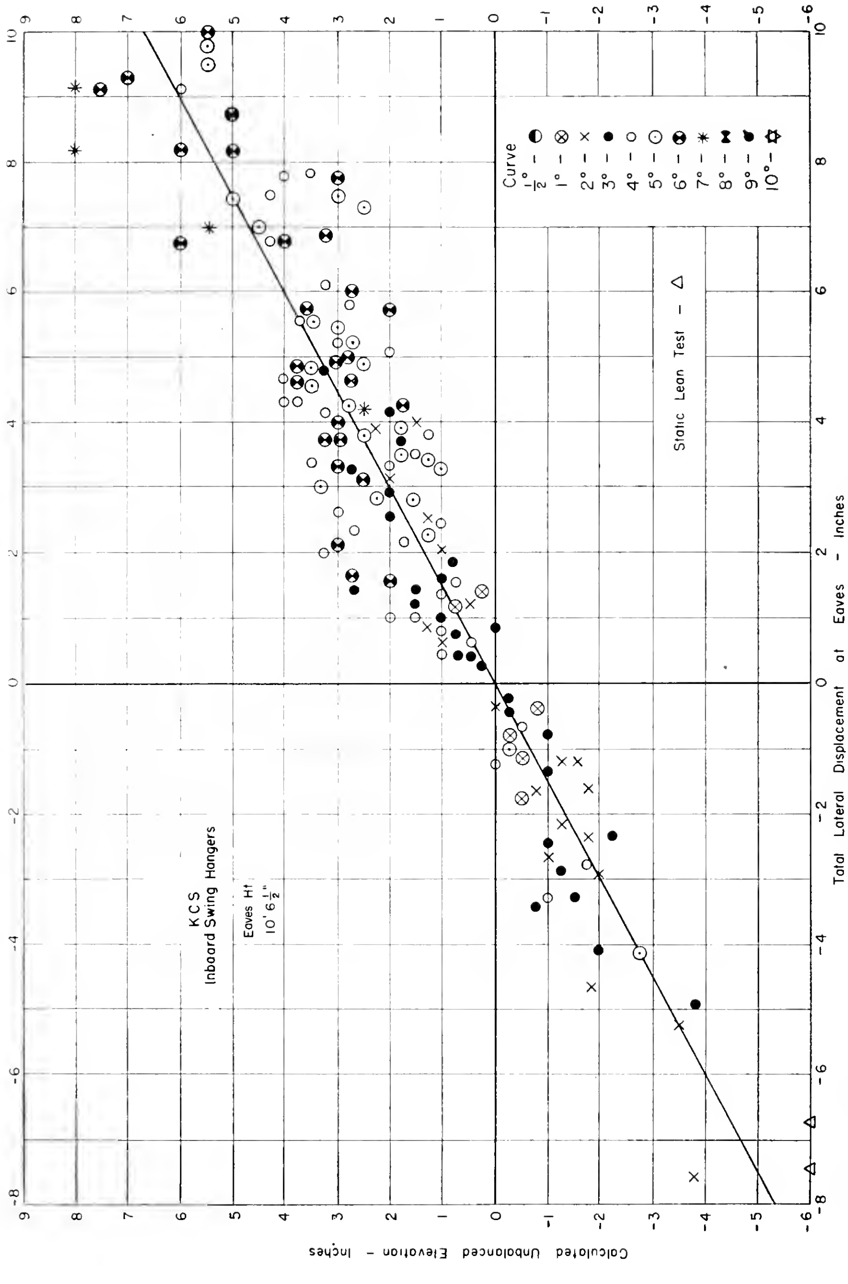


Fig 42– Relation of Static and Dynamic Displacement to Calculated Unbalanced Elevation.

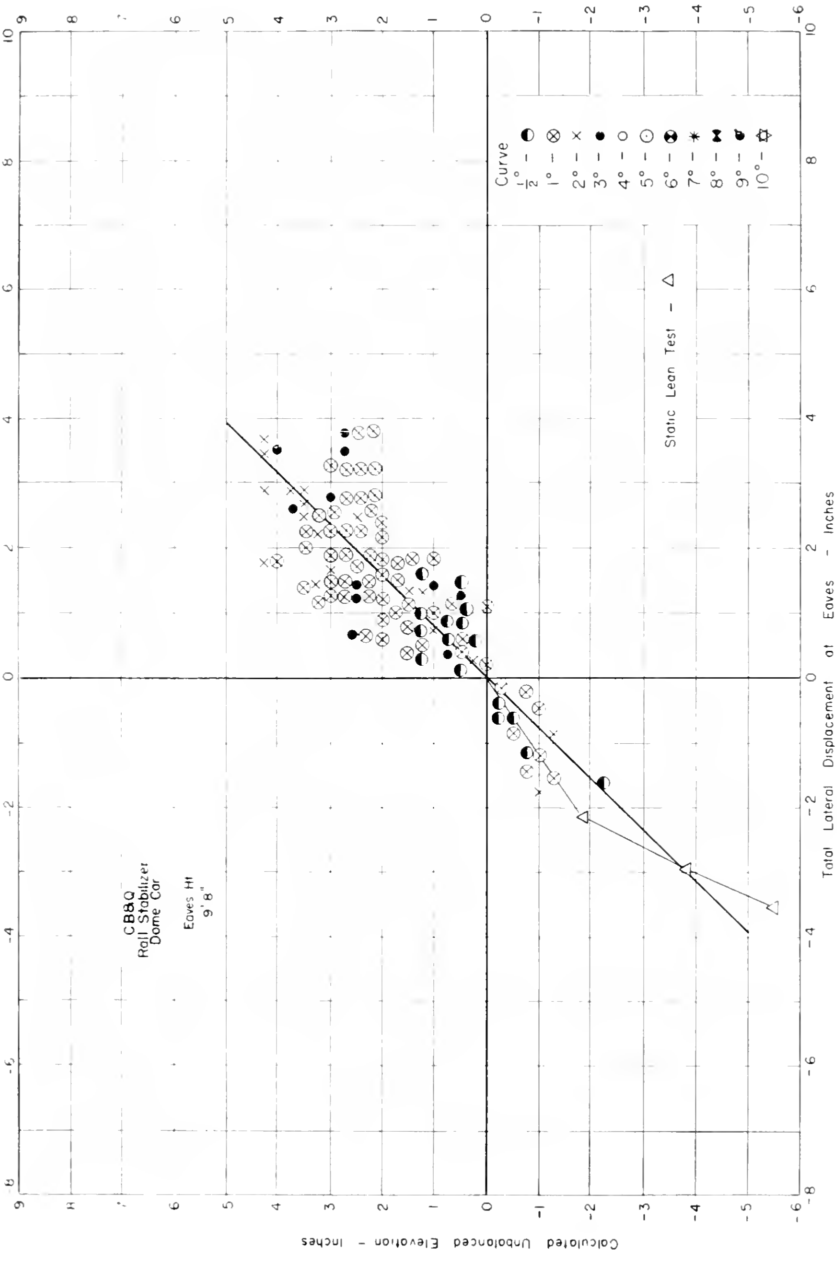


Fig 43 - Relation of Static and Dynamic Displacement to Calculated Unbalanced Elevation

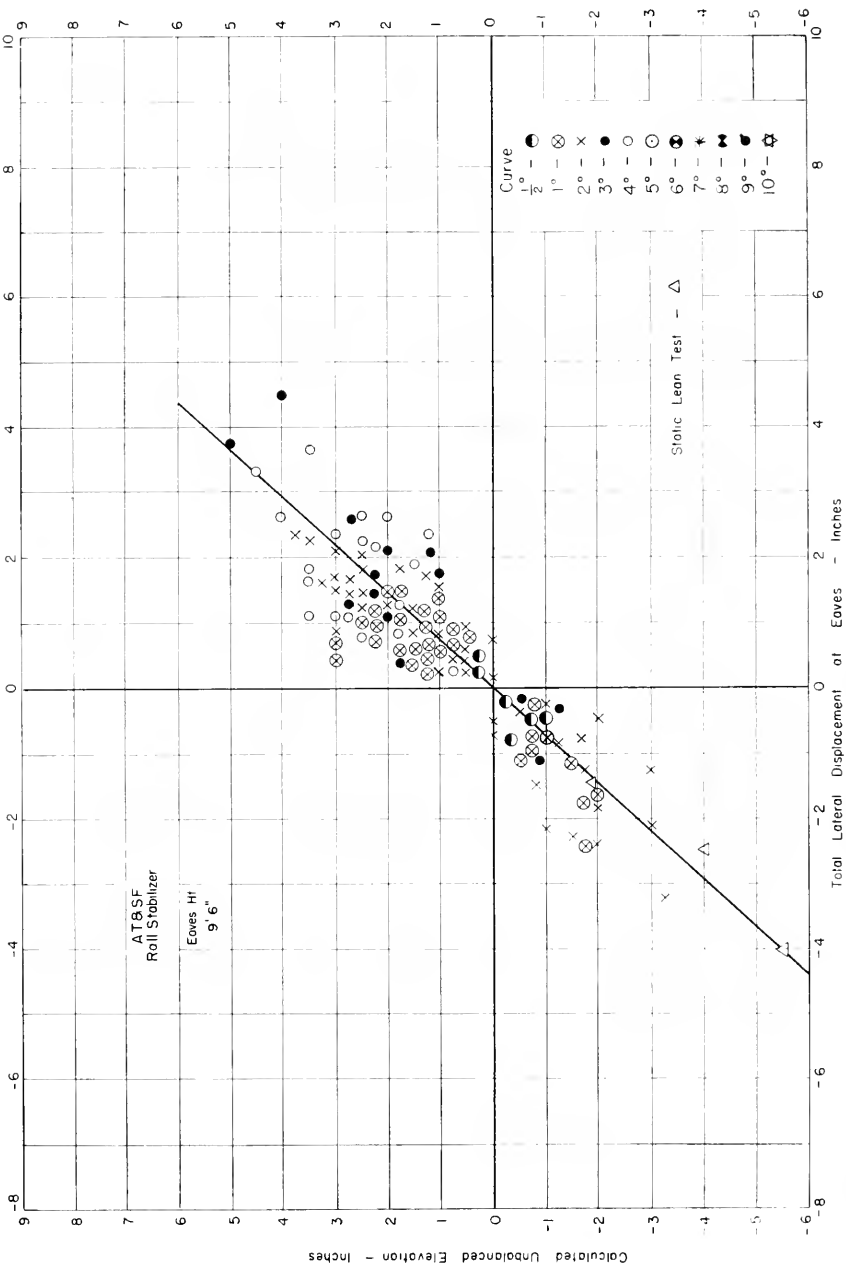


Fig 44 – Relation of Static and Dynamic Displacement to Calculated Unbalanced Elevation

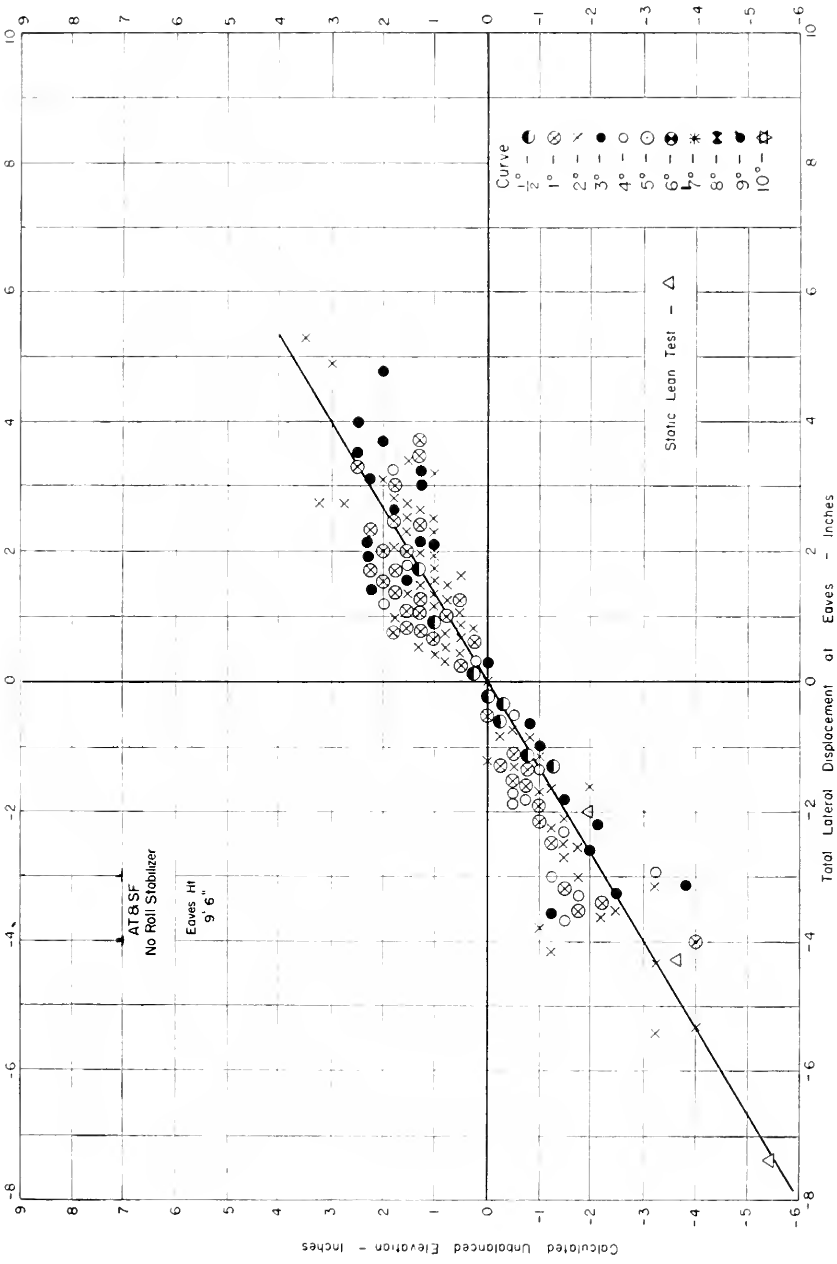


Fig 45 – Relation of Static and Dynamic Displacement to Calculated Unbalanced Elevation

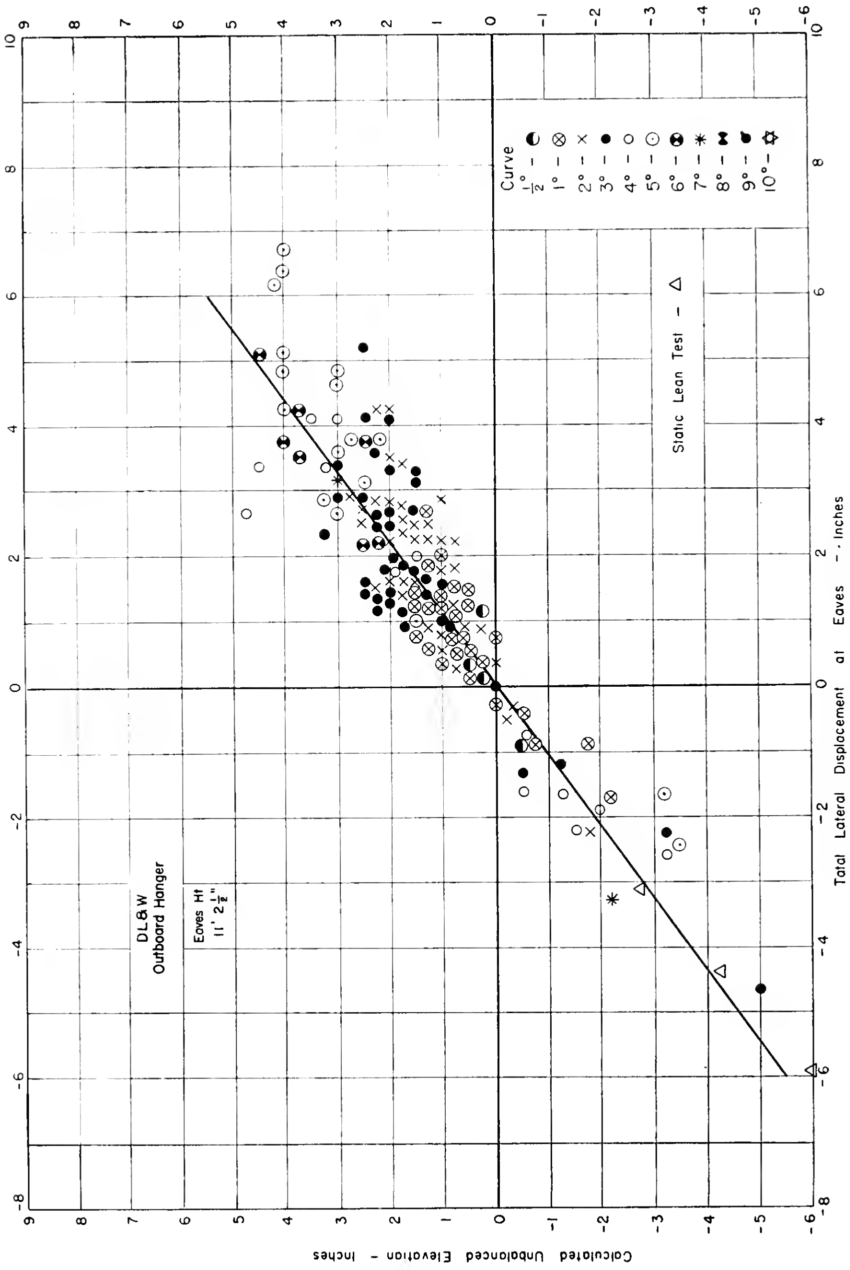


Fig 46 - Relation of Static and Dynamic Displacement to Calculated Unbalanced Elevation.

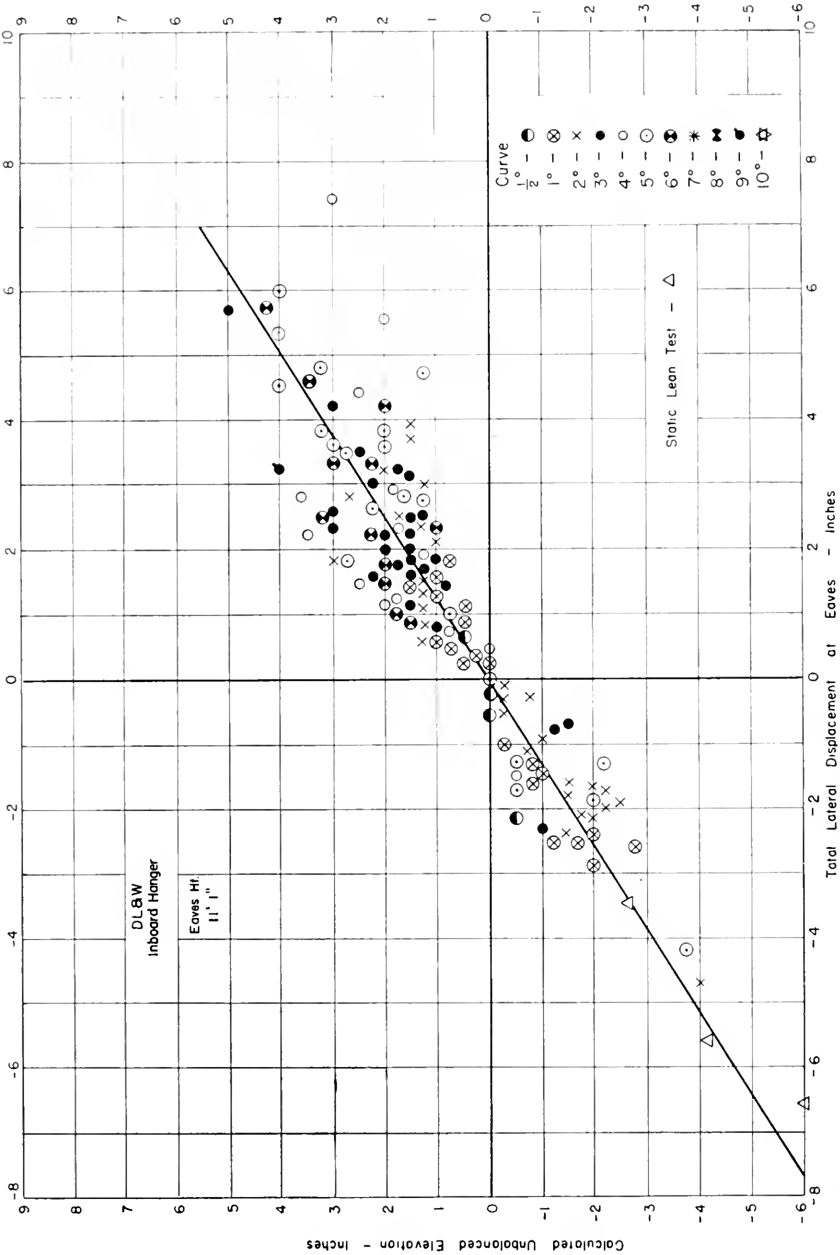


Fig 47 – Relation of Static and Dynamic Displacement to Calculated Unbalanced Elevation.

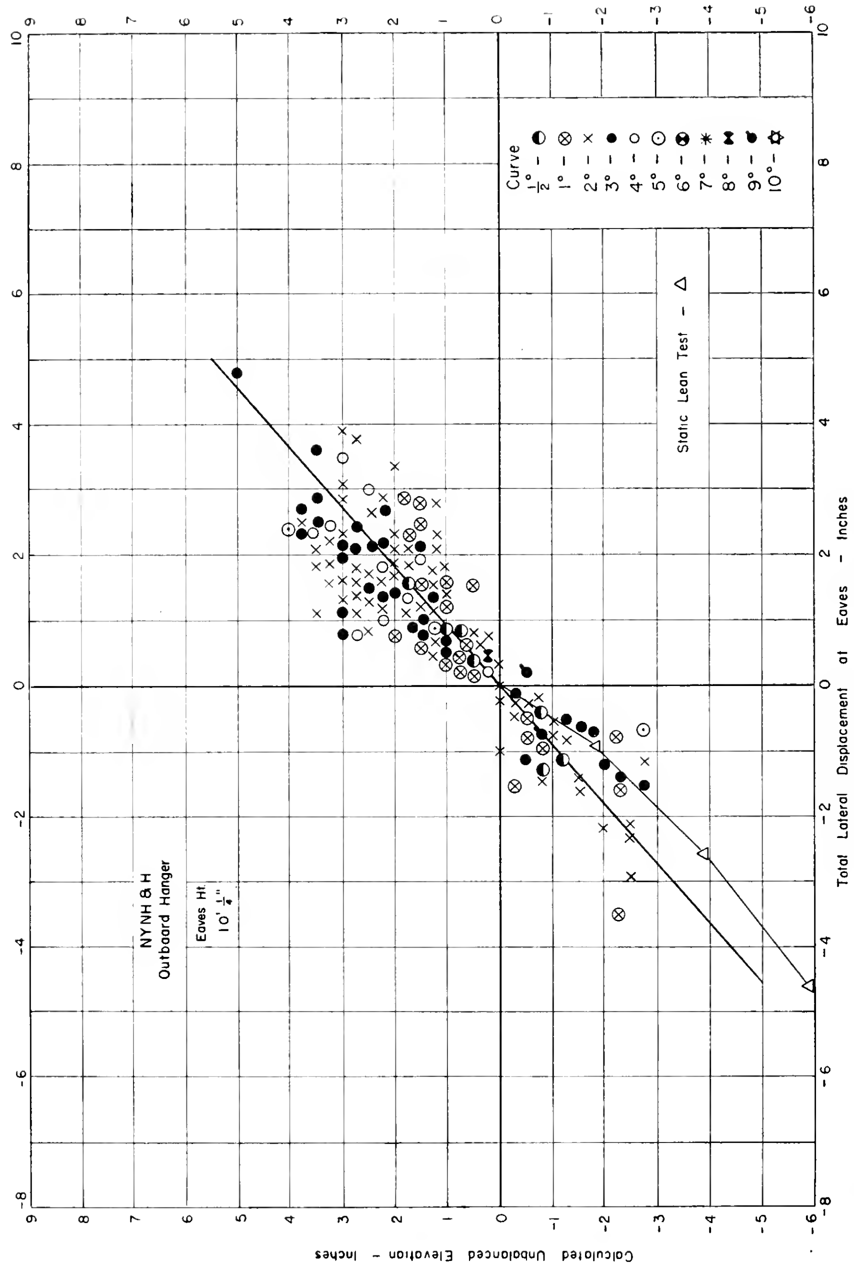


Fig. 48 – Relation of Static and Dynamic Displacement to Calculated Unbalanced Elevation.

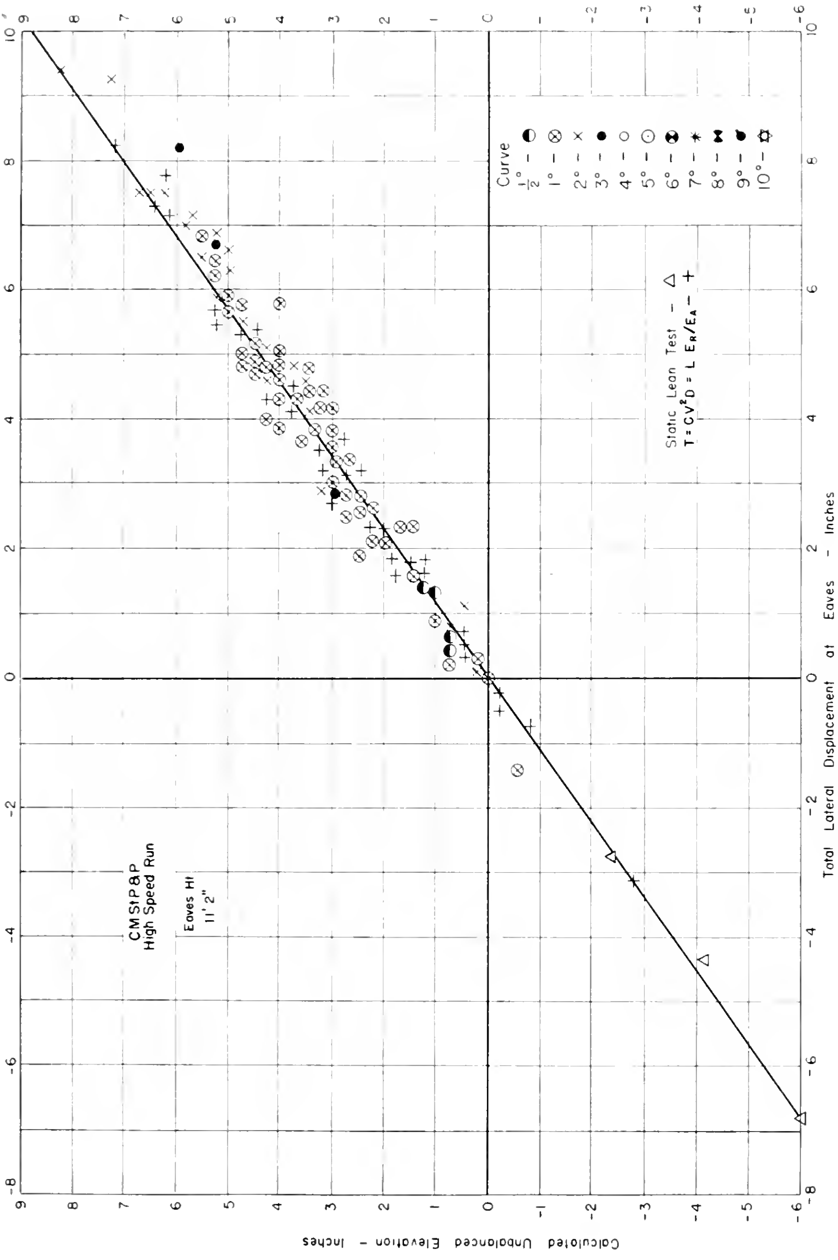


Fig 49 – Relation of Static and Dynamic Displacement to Calculated Unbalanced Elevation

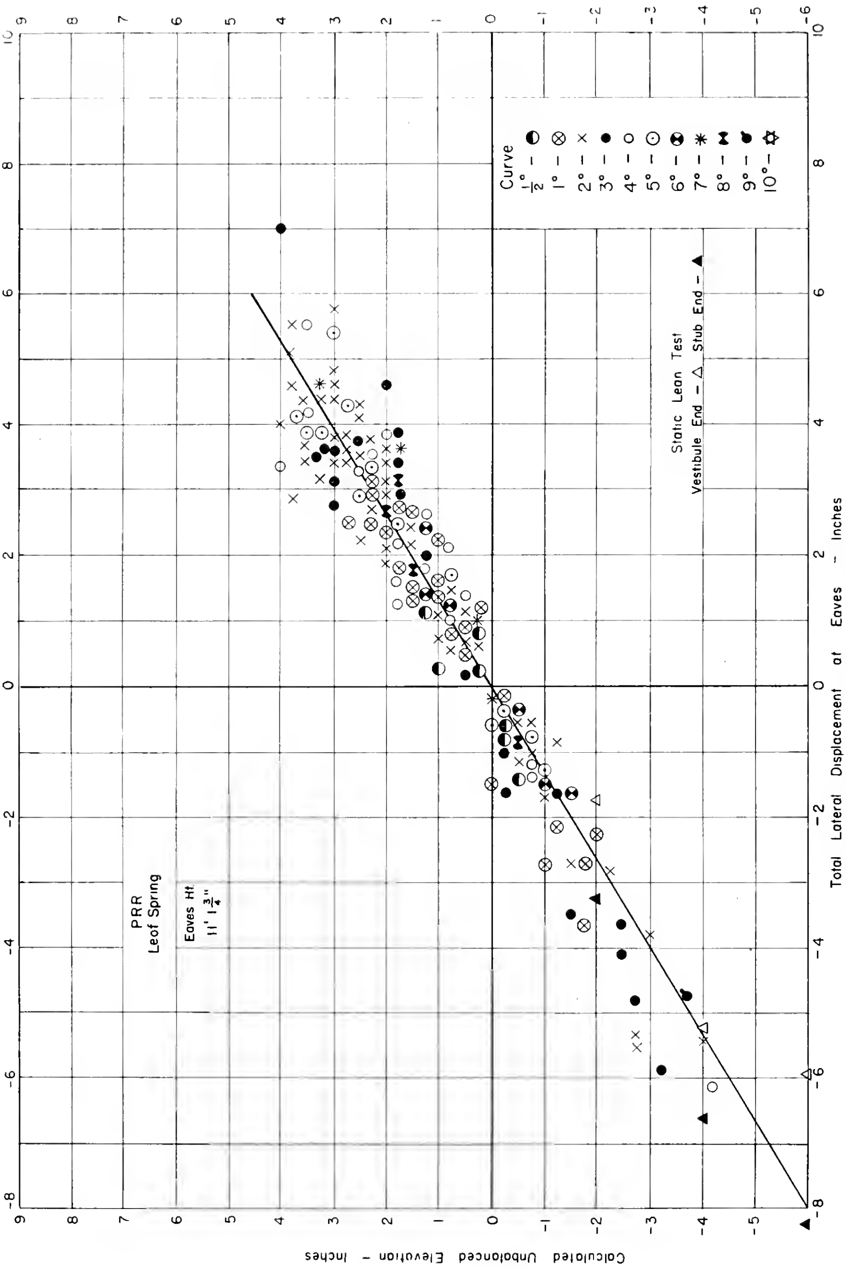


Fig. 50 – Relation of Static and Dynamic Displacement to Calculated Unbalanced Elevation.

Advance Report of Committee 3—Ties

P. D. Brentlinger, *Chairman,*	F. J. Fudge	L. C. Collister, *Vice Chairman,*
J. E. Armstrong, Jr.	W. E. Fuhr	R. H. Paschal
C. S. Burt	R. F. Garner	D. E. Patton
W. J. Burton	L. E. Gingerich	A. Price
G. B. Campbell	C. L. Heimbach	W. C. Reichow
C. M. Coates	B. D. Howe	N. B. Roberts
E. L. Collette	M. J. Hubbard	H. S. Ross
B. S. Converse	R. P. Hughes	N. A. Salzano
R. L. Cook	C. E. Jackman	C. V. Schutt
R. W. Cook	G. R. Janosko	E. F. Snyder
B. E. Crumpler	H. W. Jensen	S. Thorvaldson
L. P. Drew	L. W. Kistler	C. D. Turley
H. R. Duncan	C. M. Long	G. A. Williams
T. H. Friedlin	Roy Lumpkin	R. G. Wintrich
A. K. Frost	T. O. Manion	*Committee*

Report on Assignment 4

Tie Renewals and Costs Per Mile of Maintained Track

The annual statistics compiled by the Bureau of Railway Economics, AAR, giving information regarding the number and costs of cross ties laid in maintenance in 1953, are shown in Tables A and B. According to these statistics, three regions increased and five regions decreased renewals in 1953 as compared with 1952. For the United States tie renewals decreased, the decrease being 808,864 ties, or 2.7 percent.

The average cost of ties shown in Col. 7 of Table A increased in all regions except the New England, the average of 1953 over 1952 in the United States being 11 cents, or 3.4 percent.

Although there was a decrease in tie renewals, this was more than offset by the increase in unit cost, so that the average cost of ties per mile of maintained track increased $4 in 1953, to a total of $300.

In 1953 the 5-year average number of ties renewed per mile of maintained track was 90, indicating an average service life of over 33 years. It should be of interest to know that this 5-year average per mile has decreased every year since 1946 when it was 134 ties (representing 22.4 years of life). Thus in seven years the indicated service life average has been increased 50 percent.

The Committee on Ties
P. D. Brentlinger, *Chairman.*

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1953

	Cross ties laid in replacement					Miles of	Estimated total	Average number of cross	Number of	Number of equated gross	New wooden cross tie replacement averages			
	New	New	Total all	Ties							Per	Number	Renewal	Renewal

Table 7

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS [illegible]

Calendar year ended December 31, 19[illegible]

Road	Cross ties laid in replacement: New wooden ties untreated (1): Number	Average cost	New wooden ties treated (T): Number	Average cost	Total all new wooden ties laid: Number	Average cost	Ties other than wood (S) & second-hand (*) re-applied ties	Total ties applied	Miles of maintained tracks (item 15)	Estimate total ties in all maintained tracks (item 24)	Ties per mile of maintained track	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NEW ENGLAND REGION:																	
Bangor & Aroostook	67 10[illegible]	$2.10	2[illegible] 757	4.54	90 860	2.74	-	90 860	516.08	2 [illegible] 834	2 5[illegible]	1 8[illegible] 777	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Boston & Maine	-	-	17[illegible] 816	3.55	173 816	[illegible]	-	173 816	2 713.25	[illegible] 004 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Canadian Nat.Lines in New Eng.	-	-	1[illegible] 098	2.[illegible]	13 098	[illegible]	* 133	13 231	234.25	740 [illegible]	[illegible]	70 26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Canadian Pacific (lines in Me.)	-	-	19 432	3.56	19 432	3.56	-	19 432	216.54	6[illegible]	2 89[illegible]	1 [illegible] 997	8 [illegible]	3.1	[illegible]	[illegible]	[illegible]
Canadian Pacific (lines in Vt.)	-	-	14 508	3.10	14 508	3.10	-	14 508	123.81	371 925	3 004	651 684	4 [illegible]	[illegible]	117	[illegible]	[illegible]
Central Vermont	-	-	30 751	4.19	30 751	4.19	-	30 751	484.49	1 4[illegible] 801	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Maine Central	23 1[illegible]	2.06	7[illegible] 280	4.04	96 475	3.[illegible]	* 41 4[illegible]	137 880	1 136.82	3 401 [illegible]	[illegible]	[illegible] 408	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New York Connecting	-	-	867	4.94	867	4.94	-	867	26.30	92 75	[illegible]	54 22	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New York,New Haven & Hartford	-	-	163 [illegible]	[illegible]	163 338	3.85	S [illegible]	163 433	3 446.79	10 717 747	[illegible] 109	22 098 793	6 4[illegible]	1.5	47	[illegible]	[illegible]
Rutland	-	-	255	[illegible].42	255	[illegible].42	* 16 412	16 6[illegible]7	393.11	1 230 000	[illegible] 129	7[illegible]	2 [illegible]	[illegible]	1	-	[illegible]
Total	90 296	2.09	51[illegible] 102	[illegible].77	603 400	3.52	5[illegible] 045	661 445	[illegible] .44	2[illegible] 994 398	3 021	4[illegible] 277 941	4 [illegible]	[illegible].1	[illegible]	202	[illegible]
GREAT LAKES REGION:																	
Ann Arbor	-	-	50 022	3.81	50 022	3.81	-	50 022	397.90	1 310 754	[illegible] 043	1 555 [illegible]	[illegible]	[illegible].1	12[illegible]	[illegible]	[illegible]
Cambria & Indiana	-	-	1 796	3.99	1 796	3.99	* 152	1 948	55.66	161 [illegible]12	[illegible] 89[illegible]	111 [illegible]	1 [illegible]	1.1	[illegible]	[illegible]	[illegible]
Delaware & Hudson	-	-	146 707	3.57	146 707	3.57	-	146 707	1 320.11	4 250 218	3 195	10 [illegible]54 [illegible]	7 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Delaware,Lackawanna & Western	-	-	127 753	4.16	127 753	4.16	-	127 753	2 091.08	6 461 112	3 090	1[illegible] 147 579	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Detroit & Mackinac	7 201	1.70	3[illegible] 87[illegible]	3.27	46 073	3.02	-	46 073	269.55	813 646	[illegible] 019	[illegible] 955	-	[illegible]	171	[illegible]	[illegible]
Detroit & Toledo Shore Line	-	-	14 220	4.50	14 220	4.50	* 6	14 226	150.2[illegible]	453 [illegible]	[illegible] 018	804 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Erie	-	-	443 028	3.87	443 028	3.87	-	443 028	4 [illegible] .18	1[illegible] 371 [illegible]	[illegible]	34 8[illegible] 170	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Grand Trunk Western	-	-	116 864	[illegible].83	116 864	3.8[illegible]	-	116 864	1 8[illegible]	[illegible] 828 963	3 169	10 7[illegible]	[illegible]	[illegible]	[illegible]	24[illegible]	[illegible]
Lehigh & Hudson River	-	-	7 481	4.51	7 481	4.51	* 754	8 235	108.[illegible]	291 900	[illegible]	725 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lehigh & New England	-	-	21 088	4.17	21 088	4.17	-	21 088	237.12	717 457	[illegible] 026	76[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lehigh Valley	-	-	166 343	3.91	166 343	3.91	-	166 343	2 381.36	7 176 926	3 014	1[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Monongahela	-	-	10 917	3.72	10 917	3.72	-	10 917	247.44	735 [illegible]	2 [illegible]	1 [illegible]	4 [illegible]	1.[illegible]	44	[illegible]	[illegible]
Montour	-	-	8 134	4.65	8 134	4.65	-	8 134	72.54	208 [illegible]	2 [illegible]	244 084	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New York Central	-	-	1 980 865	3.77	1 980 865	3.77	* [illegible] 44	1 985 209	20 531.41	63 445 4[illegible]	3 090	157 570 421	[illegible]	[illegible].1	[illegible]	[illegible]	[illegible]
New York,Chicago & St.Louis	-	-	373 469	3.79	373 469	3.79	-	373 4[illegible]	3 445.71	10 734 [illegible]	3 11[illegible]	[illegible] 957 959	[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]
New York,Ontario & Western	-	-	26 002	3.88	26 002	[illegible].58	* 1[illegible] 6[illegible]7	[illegible] 629	655.62	1 850 975	2 [illegible]	1 364 [illegible]	2 [illegible]	1.4	40	1[illegible]	7.[illegible]
New York,Susquehanna & Western	-	-	8 239	4.51	8 239	4.51	-	8 239	208.75	[illegible] 425	2 [illegible]	313 543	1 5[illegible]	1.4	39	173	11.[illegible]
Pittsburgh & Lake Erie	-	-	72 813	3.94	72 813	3.94	-	72 813	795.53	2 433 938	[illegible]	4 324 070	5 435	3.0	92	361	[illegible]
Pittsburg & Shawmut	-	-	7 155	3.92	7 155	3.92	* 177	7 332	115.08	328 832	2 857	257 650	[illegible]	[illegible].2	62	[illegible]	10.[illegible]
Pittsburgh & West Virginia	-	-	16 313	4.50	16 313	4.50	-	16 313	179.98	550 513	3 059	1 115 941	[illegible]	[illegible].0	91	408	[illegible]
Wabash	-	-	269 276	3.93	269 276	3.93	-	269 276	3 169.92	9 940 235	3 136	24 572 036	[illegible]	[illegible].7	85	334	[illegible]
Total	7 201	1.70	3 907 377	3.82	3 914 578	3.81	16 060	3 930 638	42 822.62	131 581 935	3 073	311 792 666	7 [illegible]81	[illegible].0	91	[illegible]	[illegible].75
CENTRAL EASTERN REGION:																	
Akron,Canton & Youngstown	22 153	3.53	122	4.03	22 275	3.53	* 20 320	42 595	220.15	650 070	2 953	798 549	3 [illegible]	3.4	101	57	[illegible]
Baltimore & Ohio	-	-	373 901	3.07	373 901	3.07	-	373 901	10 333.51	29 411 226	2 847	91 372 671	[illegible]	1.3	26	111	1.[illegible]
Bessemer & Lake Erie	-	-	27 674	4.67	27 674	4.67	-	27 674	478.74	1 492 175	3 117	4 450 071	[illegible]	1.9	58	270	[illegible].90
Central R.R. of New Jersey	-	-	84 918	3.81	84 918	3.81	-	84 918	1 308.61	4 627 322	3 536	7 307 736	5 [illegible]4	[illegible].8	65	247	4.43
Chicago & Eastern Illinois	-	-	86 211	3.69	86 211	3.69	-	86 211	1 305.88	3 974 211	3 043	6 761 809	5 1[illegible]	[illegible]	66	244	4.[illegible]9
Chicago & Illinois Midland	-	-	8 452	3.79	8 452	3.79	-	8 452	178.24	533 776	2 995	1 233 446	6 9[illegible]	1.6	47	1[illegible]0	2.60
Chicago,Inopls.& Louisville	-	-	119 357	3.16	119 357	3.16	-	119 357	725.37	2 251 788	3 104	[illegible] 392 762	4 [illegible]77	5.3	165	521	11.[illegible]
Detroit,Toledo & Ironton	1 710	.40	80 143	3.18	81 853	3.12	-	81 853	[illegible]02.50	1 735 200	2 880	2 677 879	4 445	4.7	136	424	9.54
Elgin,Joliet & Eastern	-	-	24 973	3.38	24 973	3.38	* 8 121	33 094	852.10	2 619 [illegible]77	3 074	3 525 167	4 1[illegible]7	1.[illegible]	29	[illegible]9	[illegible]
Illinois Terminal	-	-	40 852	2.90	40 852	2.90	* 14 018	54 870	523.37	1 634 447	3 218	1 144 127	2 18[illegible]	[illegible].4	78	226	10.35
Long Island	-	-	64 370	4.03	64 370	4.03	-	64 370	768.44	2 212 224	2 879	3 721 456	4 843	2.9	84	338	6.98
Missouri-Illinois	-	-	8 881	2.76	8 881	2.76	-	8 881	216.65	680 498	3 141	443 722	2 048	1.3	41	113	5.53
Pennsylvania	-	-	2 000 574	3.82	2 000 574	3.82	* 1 318	2 001 892	21 365.91	61 259 545	2 867	188 675 978	8 831	3.3	94	357	4.05
Penna.-Reading Seashore Lines	-	-	49 963	4.50	49 963	4.50	-	49 963	559.99	1 522 007	2 718	1 173 832	2 096	3.3	89	402	19.17
Reading Co.	-	-	211 464	3.77	211 464	3.77	-	211 464	2 752.88	7 665 109	2 784	17 304 340	6 286	2.8	77	290	4.61
Staten Island Rapid Transit	-	-	6 419	3.05	6 419	3.05	-	6 419	90.98	232 912	2 560	194 085	2 133	2.8	71	215	10.08
Western Maryland	630	2.78	87 150	4.00	87 780	3.99	-	87 780	1 160.24	3 471 106	2 992	8 223 853	7 088	2.5	76	302	4.26
Total	24 493	3.29	3 275 424	3.69	3 299 917	3.69	43 777	3 343 694	43 443.56	126 032 999	2 901	342 421 483	7 [illegible]	2.6	76	280	[illegible].56
POCAHONTAS REGION:																	
Atlantic & Danville	72	1.96	20 808	2.79	20 880	2.79	-	20 880	233.84	675 000	2 887	319 003	1 [illegible]64	3.1	89	249	18.24
Chesapeake & Ohio	-	-	646 888	3.47	646 888	3.47	-	646 888	8 145.36	24 669 005	3 029	72 344 458	8 [illegible]	[illegible].6	79	[illegible]76	3.11
Norfolk & Western	-	-	499 299	3.22	499 299	3.22	* 4 962	504 261	4 341.96	13 460 076	3 100	45 729 442	10 [illegible]	3.7	115	370	[illegible].52
Richmond,Fred'burg & Potomac	-	-	39 891	3.73	39 891	3.73	* 3 811	43 702	412.58	1 230 100	2 981	5 160 414	12 508	[illegible].2	[illegible]7	[illegible]1	[illegible]
Virginian	-	-	108 727	3.28	108 727	3.28	* 178	108 905	952.92	2 927 155	3 072	8 127 716	8 540	[illegible].7	114	74	4.[illegible]
Total	72	1.96	1 315 613	3.36	1 315 685	3.36	8 951	1 324 636	14 086.66	42 961 336	3 050	131 691 033	9 [illegible]	3.1	93	314	3.16
SOUTHERN REGION:																	
Alabama Great Southern	-	-	46 096	3.66	46 096	3.66	-	46 096	577.99	1 743 215	3 016	4 529 869	7 [illegible]37	2.6	80	292	[illegible].73
Atlanta & St.Andrews Bay	-	-	13 125	4.43	13 125	4.43	-	13 125	119.28	362 022	3 035	605 230	5 074	3.6	110	487	9.61
Atlanta & West Point	13	1.50	24 989	3.62	25 002	3.62	-	25 002	147.63	440 374	2 953	785 339	5 [illegible]	5.7	169	[illegible]13	11.53
Atlantic Coast Line	-	-	1 110 633	3.37	1 110 633	3.37	-	1 110 633	7 249.86	22 474 566	3 100	40 337 270	[illegible] 564	4.9	153	517	9.29
Central of Georgia	-	-	228 352	3.07	228 352	3.07	-	228 352	2 286.97	6 618 129	2 894	[illegible] 295 777	4 065	3.5	100	306	7.53
Charleston & Western Carolina	-	-	83 997	3.99	83 997	3.99	* 50	84 047	439.64	1 262 692	2 918	1 248 942	2 [illegible]41	6.5	191	762	26.[illegible]
Cin.,New Orleans & Tex.Pac.	-	-	66 218	3.73	66 218	3.73	-	66 218	679.45	2 012 089	2 961	9 784 309	14 400	[illegible].3	97	[illegible]	[illegible]
Clinchfield	-	-	195 900	3.25	195 900	3.25	-	195 900	428.40	1 370 873	3 200	4 808 04[illegible]	11 2[illegible]	14.3	457	1487	[illegible].25
Columbus & Greenville	-	-	20 227	2.53	20 227	2.53	-	20 227	205.39	650 676	3 168	222 [illegible]24	1 084	3.1	98	249	[illegible].58
Florida East Coast	2 688	2.08	153 479	3.67	156 167	3.65	* 31	156 198	1 161.14	3 370 021	2 90[illegible]	6 801 50[illegible]	5 [illegible]	4.6	134	490	8.37
Georgia	1[illegible]	1.[illegible]	71 [illegible]	3.33	71 769	3.33	-	71 769	442.37	1 344 71[illegible]	3 040	1 66[illegible] 734	[illegible]	[illegible].3	162	[illegible]41	11.[illegible]
Georgia & Florida	57 510	1.99	46 086	3.11	103 596	2.49	-	103 596	413.80	1 117 260	2 700	672 057	1 624	9.3	250	623	3[illegible].[illegible]7
Georgia,Southern & Florida	-	-	80 018	3.49	80 018	3.49	* 12 346	92 364	474.36	1 490 724	3 143	2 275 384	4 7[illegible]	[illegible].4	169	528	12.26
Gulf,Mobile & Ohio	-	-	460 160	3.09	460 160	3.09	* 8 583	468 743	3 501.69	11 093 353	3 168	18 312 356	[illegible] 230	4.1	131	406	[illegible].77
Illinois Central	-	-	993 059	3.17	993 059	3.17	S 27	993 086	9 952.41	[illegible] 043 [illegible]71	[illegible]	[illegible] 310 378	[illegible]	[illegible]	101	319	4.77
Louisville & Nashville	-	-	860 111	3.07	860 111	3.07	-	860 111	6 724.01	19 318 205	[illegible] 873	40 845 343	6 [illegible]67	4.[illegible]	128	[illegible]92	[illegible]
Mississippi Central	-	-	37 426	3.10	37 426	3.10	* 150	37 576	173.84	552 527	3 178	[illegible]48 777	2 0[illegible]7	6.8	215	668	33.26
Nashville,Chatt.& St.Louis	-	-	214 372	3.27	214 372	3.27	-	214 372	1 425.26	3 869 511	[illegible] 736	7 90[illegible] 45[illegible]	5 [illegible]	5.[illegible]	150	492	8.27
New Orleans & Northeastern	-	-	19 673	3.91	19 673	3.91	-	19 673	294.79	868 318	[illegible] 957	[illegible] 4[illegible]9 44[illegible]	8 [illegible]	2.3	67	262	3.17
Norfolk Southern	83 803	1.73	101 191	2.92	184 994	2.38	* 9 820	194 814	742.55	2 169 910	[illegible] 923	1 709 101	2 302	8.5	24[illegible]	592	[illegible]
Seaboard Air Line	-	-	391 696	3.45	391 696	3.45	-	391 696	5 441.30	16 426 04[illegible]	3 019	34 417 517	6 325	[illegible].4	7[illegible]	24[illegible]	[illegible].63
Southern Ry.	129	2.17	689 875	3.56	690 204	3.56	-	690 204	8 386.46	26 013 428	3 102	50 477 216	6 19[illegible]	[illegible].7	8[illegible]	29[illegible]	4.87
Tennessee Central	477	.68	37 877	3.11	38 354	3.08	-	38 354	349.64	1 058 716	[illegible]028	666 866	1 907	3.6	110	339	17.7[illegible]
Western Ry.of Alabama	-	-	31 562	3.62	31 562	3.62	-	31 562	187.24	561 573	2 991	951 173	5 [illegible]77	5.6	168	609	12.00
Total	144 928	1.84	5 977 783	3.30	6 122 711	3.26	31 007	6 153 718	51 704.27	156 251 634	3 023	313 139 266	6 0[illegible]8	3.9	118	386	6.37

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1953

	Cross ties laid in replacement					Miles of	Estimated total	Average number of	Number of	Number of equated	New wooden cross tie replacement averages			
				Ties										

Table A

CROSS TIE STATISTICS (EXCLUDING SWITCH & BRIDGE) FOR CLASS I RAILROADS IN THE UNITED STATES AND LARGE CANADIAN RAILROADS

Calendar year ended December 31, 1953

Road	Cross ties laid in replacement								Miles of main-tained tracks (item 25)	Estimated total cross ties in all maintained tracks (item 24)	Average number of cross ties per mile of main-tained track	Number of equated gross ton-miles a (thousands)	Number of equated gross ton-miles per mile of main-tained track (thous.)	New wooden cross tie replacement averages			
	New wooden ties untreated (U)		New wooden ties treated (T)		Total all new wooden ties laid		Ties other than wood (S) & second-hand(*) reapplied ties	Total ties applied						Per cent renewal to all ties in main-tained track	Number laid per mile of main-tained track	Renewal cost per mile of main-tained track	Renewal cost per 1000 equated gross ton-miles
	Number	Aver-age cost	Number	Aver-age cost	Number	Aver-age cost											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
NORTHWESTERN REGION:																	(cents)
Chicago & North Western	13 761	$1.40	829 952	$3.47	843 753	$3.43	-	843 753	10 915.67	32 334 683	2 962	44 280 727	4 057	2.6	77	$265	6.54
Chicago Great Western	-	-	134 332	3.97	134 332	3.97	-	134 332	1 791.87	5 357 171	2 990	7 459 340	4 163	2.5	75	297	7.14
Chicago,Milwaukee,St.Paul & Pac.	125 395	.33	725 638	3.17	851 033	2.75	-	851 033	13 389.30	41 218 428	3 078	58 209 212	4 347	2.1	64	175	4.02
Chicago,St.Paul,Minpls.& Omaha	1 641	1.61	161 719	3.65	163 360	3.63	-	163 360	2 138.32	6 340 376	2 965	7 187 704	3 361	2.6	76	278	8.26
Duluth,Missabe & Iron Range	229	1.71	70 715	3.28	70 944	3.28	-	70 944	1 065.63	3 174 528	2 979	8 792 965	8 251	2.2	67	219	2.64
Duluth,South Shore & Atlantic	2 479	1.70	101 375	3.24	103 854	3.20	-	103 854	560.54	1 624 971	2 899	1 715 494	3 066	6.4	185	593	19.35
Duluth,Winnipeg & Pacific	1 902	2.09	13 531	2.91	15 433	2.81	-	15 433	205.80	589 439	2 864	1 025 175	4 981	2.6	75	211	4.23
Great Northern	180	1.94	909 964	3.73	910 144	3.73	* 48 887	959 031	10 271.50	31 997 294	3 115	60 642 420	5 904	2.8	89	331	5.60
Green Bay & Western	4 806	2.32	48 134	3.65	52 940	3.53	-	52 940	275.39	793 123	2 880	667 106	2 422	6.7	192	679	28.04
Lake Superior & Ishpeming	7 961	1.55	11 935	3.48	19 896	2.71	-	19 896	258.02	793 761	3 076	204 029	791	2.5	77	209	26.40
Minneapolis & St.Louis	42 475	1.68	210 459	3.22	252 934	2.96	-	252 934	1 534.42	4 619 844	3 011	3 786 922	2 468	5.5	165	488	19.76
Minpls.,St.Paul & S.S.M.(Inc.WC)	2 859	1.50	484 079	3.43	486 938	3.42	-	486 938	4 805.57	14 451 427	3 079	18 952 167	3 944	3.4	101	346	8.78
Northern Pacific	1 078	1.35	495 629	3.34	496 707	3.34	-	496 707	9 227.68	26 786 309	2 903	45 213 257	4 900	1.9	54	180	3.67
Spokane International	365	2.06	75 546	3.35	75 911	3.34	-	75 911	175.83	513 598	2 921	428 259	2 436	14.8	432	1443	59.23
Spokane,Portland & Seattle	-	-	62 056	3.87	62 056	3.87	-	62 056	1 135.98	3 629 503	3 195	6 366 469	5 604	1.7	55	212	3.77
Total	205 131	.85	4 335 104	3.46	4 540 235	3.34	48 887	4 589 122	57 751.52	174 234 655	3 017	264 934 246	4 587	2.6	79	263	5.73
CENTRAL WESTERN REGION:																	
Atchison,Topeka & Santa Fe	-	-	1 319 929	3.11	1 319 929	3.11	-	1 319 929	19 498.34	62 258 198	3 193	161 442 753	8 280	2.1	68	211	2.54
Chicago,Burlington & Quincy	-	-	685 601	3.35	685 601	3.35	*138 560	824 161	11 779.08	36 373 799	3 088	65 763 899	5 583	1.9	58	195	3.49
Chicago,Rock Island & Pacific	414	3.04	802 740	2.69	803 154	2.69	-	803 154	9 875.33	29 452 338	2 982	48 358 785	4 897	2.7	81	218	4.46
Colorado & Southern	-	-	54 680	3.33	54 680	3.33	* 1 959	56 639	811.95	2 435 850	3 000	4 017 837	4 948	2.2	67	224	4.53
Colorado & Wyoming	-	-	3 038	3.82	3 038	3.82	-	3 038	106.00	328 005	3 094	47 063	444	0.9	29	109	24.66
Denver & Rio Grande Western	-	-	259 632	4.15	259 632	4.15	* 38 272	297 904	3 295.81	10 217 000	3 100	19 283 869	5 851	2.5	79	327	5.59
Fort Worth & Denver	-	-	86 307	3.17	86 307	3.17	* 2 783	89 090	1 215.72	3 661 199	3 012	4 989 593	4 104	[illegible]	71	225	[illegible]
Northwestern Pacific	10 904	2.73	93 971	3.34	104 875	3.28	* 128	125 003	428.75	1 235 613	2 882	2 048 067	4 777	[illegible]	245	80[illegible]	[illegible]
Sacramento Northern	62	2.94	17 484	3.42	17 546	3.42	-	17 546	306.44	933 815	3 047	126 406	412	1.9	57	196	47.4[illegible]
Southern Pacific Co.-Pac.Lines	4 031	2.26	[illegible]	3.34	697 076	3.23	* 4 298	901 374	12 [illegible].41	35 958 698	2 976	128 213 384	10 [illegible]	2.5	74	240	[illegible]
Toledo,Peoria & Western	-	-	24 631	3.50	24 631	3.50	-	24 631	281.40	891 475	3 168	1 027 446	3 651	2.8	86	306	3.38
Union Pacific	363	2.28	[illegible]	3.47	974 258	3.47	-	974 258	13 423.53	37 952 009	2 827	150 017 292	11 17[illegible]	[illegible]	73	252	[illegible]
Utah	108	[illegible]	1 531	3.90	1 639	3.82	* 299	1 938	70.16	200 394	2 856	249 390	3 555	0.8	23	59	2.51
Western Pacific	11 440	3.54	208 948	4.01	220 388	3.99	* 1 646	222 034	1 550.82	4 614 306	2 975	12 908 234	8 3[illegible]	4.8	142	567	5.91
Total	27 322	3.00	5 425 432	3.27	5 452 754	3.27	187 945	5 640 699	74 691.74	226 412 699	3 031	598 494 018	3 013	2.4	73	239	2.98
SOUTHWESTERN REGION:																	
Beaumont,Sour Lake & Western	-	-	26 094	2.95	26 094	2.95	-	26 094	150.33	447 600	2 977	1 355 133	9 014	5.8	174	512	5.38
International-Great Northern	-	-	237 241	2.91	237 241	2.91	-	237 241	1 346.59	4 257 900	[illegible]	7 890 623	5 [illegible]	5.6	176	513	8.76
Kansas City Southern	26	1.27	239 106	3.20	239 132	3.20	-	239 132	1 312.87	4 153 863	3 164	11 106 527	8 4[illegible]	5.8	182	582	6.88
Kansas,Oklahoma & Gulf	26	.53	47 560	2.98	47 586	2.98	-	47 586	354.25	1 058 502	2 988	1 502 597	4 242	4.5	134	400	9.43
Louisiana & Arkansas	-	-	122 039	3.08	122 039	3.08	-	122 039	888.84	2 890 305	3 252	4 832 451	5 437	4.2	137	422	7.77
Midland Valley	-	-	28 691	2.87	28 691	2.87	-	28 691	348.50	1 037 981	2 978	484 894	1 391	2.8	[illegible]	237	17.31
Missouri-Kansas-Texas Lines	200	1.73	500 283	2.80	500 483	2.80	-	500 483	3 925.32	12 390 800	3 157	17 997 383	4 585	4.0	128	357	7.78
Missouri Pacific	373	.97	1 068 495	3.03	1 068 868	3.03	-	1 068 868	8 784.39	27 092 152	3 084	56 414 028	6 432	3.9	122	368	[illegible]
New Orleans,Texas & Mexico	-	-	42 069	2.95	42 069	2.95	-	42 069	227.78	696 800	3 059	1 572 737	6 905	6.0	185	545	7.90
Oklahoma City-Ada-Atoka	-	-	18 349	2.89	18 349	2.89	-	18 349	136.63	393 868	2 883	93 512	684	4.7	134	388	56.75
St.Louis,Brownsville & Mexico	-	-	107 454	2.85	107 454	2.85	-	107 454	779.05	2 356 660	3 025	2 720 772	3 492	4.6	138	[illegible]	[illegible]
St.Louis-San Francisco	15	2.47	467 975	2.88	467 990	2.88	-	467 990	5 794.71	18 318 402	3 161	29 297 356	5 056	2.6	81	232	4.59
St.Louis,San Fran.& Texas	-	-	15 416	2.83	15 416	2.83	-	15 416	157.37	491 004	3 120	781 539	4 966	3.1	98	278	7.59
St.Louis Southwestern Lines	-	-	258 640	2.93	258 640	2.92	* 4 148	262 788	1 736.50	5 412 154	3 117	13 564 493	7 811	4.9	149	437	5.59
San Antonio,Uvalde & Gulf	-	-	54 887	2.84	54 887	2.84	-	54 887	366.54	1 026 100	2 797	703 884	1 919	5.3	150	4.5	3.11
Texas & New Orleans	-	-	588 240	2.61	588 240	2.61	-	588 240	5 561.61	15 318 062	2 754	33 930 823	6 101	3.8	106	27[illegible]	4.72
Texas & Northern	-	-	1 727	2.88	1 727	2.88	-	1 727	12.73	48 311	3 795	29 577	2 347	.6	136	390	1.64
Texas & Pacific	-	-	312 301	2.85	312 301	2.85	-	312 301	2 244.56	6 571 318	2 928	19 156 547	8 545	4.8	139	396	4.54
Texas Mexican	-	-	23 260	3.26	23 260	3.26	-	23 260	234.91	744 195	3 168	237 219	1 010	3.1	99	323	32.01
Total	640	1.24	4 159 827	2.90	4 160 467	2.90	4 148	4 164 615	34 363.76	104 705 917	3 047	203 702 395	5 925	4.0	121	371	[illegible]
Grand total - United States	500 085	1.51	28 909 662	3.39	29 409 747	3.36	398 820	29 808 567	328 462.59	991 205 573	3 018	2 213 613 445	6 739	3.0	90	[illegible]	4.4[illegible]
CANADIAN ROADS:																	
Canadian National	383 538	1.77	3 499 843	3.07	3 883 381	2.94	-	3 883 381	27 980.00	81 663 125	2 919	b	b	4.8	139	4[illegible]	b
Canadian Pacific	89 715	2.26	2 622 547	3.21	2 712 262	3.18	-	2 712 262	21 258.50	61 390 418	2 888	109 431 100	[illegible]	4.4	128	407	7.8
Ontario & Northland	21 129	2.42	197 396	4.26	213 525	4.08	-	213 525	673.70	1 971 170	2 900	1 604 205	[illegible]	11.1	[illegible]	[illegible]	[illegible]

a Gross ton-miles of cars and contents, plus two times gross ton-miles of locomotives and tenders in freight service, plus three times gross ton-miles of locomotives and tenders in passenger service.
b Not reported.

Note: "Average cost" as shown in Columns 3, 5 and 7, represents storekeepers average cost of ties charged out and used. They are not the actual costs or the prices paid for the ties purchased during the period.

Compiled by
Association of American Railroads, Bureau of Railway Economics, Washington, D.C.,
from Annual Reports of Class I Railways to the Interstate Commerce Commission.
May 26, 1954

Table B

NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOOD CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of five years 1949 to 1953, inclusive

Note: All figures are exclusive of bridge and switch ties

Table 9

NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW [illegible] CROSS TIE RENEWALS T[illegible] TAL [illegible]

Class I roads in the United States and large Canadian roads, by years, and for the average of five years 1949 to 19[illegible], inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wood cross tie renewals per mile of maintained track: 1949	1950	1951	1952	1953	5 year average	Aggregate cost of new wood cross tie renewals per mile of maintained track: 1949	1950	1951	1952	19[illegible]	5 year average	Per [illegible] wood cross tie renewals [illegible] ties in track: 1949	19[illegible]	1951	1952	1953	5 year average
NEW ENGLAND REGION:																		
Bangor & Aroostook	223	167	141	149	111	158	$359	$304	$305	$437	$334	$342	7.[illegible]	5.8	4.[illegible]	5.[illegible]	3.3	5.5
Boston & Maine	49	64	52	69	64	60	156	215	180	280	228	212	1.7	2.2	1.8	2.3	2.2	2.0
Canadian Nat. Lines in New England	78	75	53	53	56	63	175	168	123	150	158	155	2.5	2.4	1.7	1.7	1.8	2.[illegible]
Canadian Pacific (lines in Me.)	100	91	86	103	90	94	244	206	208	295	219	254	3.5	3.1	[illegible]	3.6	3.1	3.[illegible]
Canadian Pacific (lines in Vt.)	58	104	119	143	117	108	128	211	289	371	364	273	1.7	3.5	4.0	4.8	3.9	3.5
Central Vermont	49	49	58	57	63	55	147	134	165	220	263	186	1.6	1.7	2.0	1.9	2.1	1.[illegible]
Maine Central	108	1[illegible]5	64	118	85	96	306	276	230	477	302	318	3.6	3.5	2.1	3.9	2.8	3.2
New York Connecting	93	91	28	52	33	59	369	377	116	251	153	255	2.9	2.9	0.9	1.7	1.1	1.9
New York, New Haven & Hartford	44	60	28	44	47	45	146	189	88	164	162	154	1.4	1.9	0.9	1.4	1.5	1.4
Rutland	57	32	21	1	1	22	172	105	65	3	2	69	1.8	1.0	0.7	0.03	0.02	0.7
Total	71	76	52	70	63	66	190	210	158	257	221	207	2.3	2.5	1.7	2.3	2.1	2.2
GREAT LAKES REGION:																		
Ann Arbor	119	117	123	103	126	118	366	363	388	371	480	394	3.9	3.9	4.1	3.4	4.1	3.9
Cambria & Indiana	28	21	12	20	32	23	87	68	43	85	129	82	1.0	0.7	0.4	0.7	1.1	0.8
Delaware & Hudson	115	107	106	98	110	107	373	354	350	339	394	362	3.5	3.4	3.3	3.2	3.5	3.4
Delaware, Lackawanna & Western	91	79	69	71	61	74	313	268	247	279	254	272	3.0	2.6	2.2	2.3	2.0	2.4
Detroit & Mackinac	136	113	231	176	171	165	284	243	702	520	517	453	4.5	3.7	7.6	5.8	5.7	5.5
Detroit & Toledo Shore Line	60	119	67	63	95	81	193	400	303	287	426	322	2.0	3.9	2.2	2.1	3.1	2.7
Erie	79	74	80	97	98	86	259	242	283	34[illegible]	378	300	2.7	2.[illegible]	[illegible].7	3.2	3.3	2.[illegible]
Grand Trunk Western	103	105	107	95	64	95	276	291	214	352	243	295	3.3	3.3	3.4	[illegible]	2.0	3.[illegible]
Lehigh & Hudson River	54	55	59	64	69	61	204	184	200	315	312	243	2.0	2.0	2.2	2.5	2.6	2.3
Lehigh & New England	111	120	110	88	89	104	354	438	432	356	370	390	3.7	4.0	3.6	2.9	2.9	[illegible].4
Lehigh Valley	86	75	76	70	70	75	262	253	244	264	272	263	2.9	2.7	2.5	[illegible]	2.3	2.[illegible]
Monongahela	46	4[illegible]	65	61	44	51	154	128	220	214	164	176	1.[illegible]	1.4	[illegible]	2.1	1.[illegible]	1.[illegible]
Montour	63	86	94	76	112	67	264	331	4[illegible]2	357	[illegible]	3[illegible]7	[illegible]	[illegible]	3.[illegible]	[illegible]	[illegible]	[illegible]
New York Central	58	69	63	85	96	74	190	225	236	323	263	26[illegible]	[illegible].0	[illegible]	[illegible].1	2.[illegible]	.1	[illegible]
New York, Chicago & St. Louis (incl. W&LE)	117	101	87	89	108	100	353	305	265	[illegible]16	411	330	3.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New York, Ontario & Western	-	53	49	19	47	32	-	75	71	77	154	75	-	1.8	[illegible]	[illegible]	1.[illegible]	1.1
New York, Susquehanna & Western	68	28	43	49	39	45	228	81	1[illegible]7	[illegible]31	17[illegible]	181	2.3	1.[illegible]	[illegible]	[illegible].7	1.[illegible]	[illegible]
Pittsburgh & Lake Erie	107	95	77	57	92	86	240	321	254	[illegible]19	[illegible]61	297	3.5	[illegible].1	[illegible].5	1.9	[illegible]	[illegible]
Pittsburg & Shawmut	106	57	97	96	62	83	333	175	405	290	24[illegible]	309	3.7	1.[illegible]	[illegible].4	3.4	[illegible]	[illegible]
Pittsburgh & West Virginia	73	102	113	104	91	92	276	251	4[illegible]	4[illegible]	4[illegible]	391	2.5	4.4	3.7	3.4	[illegible]	[illegible]
Wabash	44	92	86	76	85	87	281	296	285	293	334	298	3.0	3.2	[illegible].7	2.4	[illegible]	2.8
Total	76	78	75	84	91	81	241	251	259	316	344	283	2.6	[illegible]	[illegible].4	2.7	[illegible]	[illegible]
CENTRAL EASTERN REGION:																		
Akron, Canton & Youngstown	150	56	113	12[illegible]	101	109	424	165	362	427	357	347	5.1	1.9	3.8	4.1	3.4	[illegible].7
Baltimore & Ohio	44	104	88	56	36	66	115	290	252	168	111	197	1.6	3.7	3.1	2.0	1.3	2.[illegible]
Bessemer & Lake Erie	28	54	61	58	58	52	109	221	253	279	170	226	0.9	1.7	2.0	1.9	1.9	1.[illegible]
Central R.R. of N.J. (incl. CRRofPa)	69	54	70	58	65	63	226	198	238	225	247	226	2.5	1.[illegible]	2.5	2.1	1.8	[illegible]
Chicago & Eastern Illinois	47	38	50	65	66	53	134	137	179	240	244	187	1.5	1.[illegible]	1.7	2.1	[illegible]	1.7
Chicago & Illinois Midland	98	80	118	51	47	79	327	293	416	201	180	283	3.3	2.6	[illegible].9	1.7	1.6	[illegible]
Chicago, Indianapolis & Louisville	141	175	218	133	165	166	378	470	632	405	521	481	4.5	5.[illegible]	7.0	4.3	5.[illegible]	[illegible]
Detroit, Toledo & Ironton	102	90	114	96	139	108	350	241	328	300	424	309	3.6	3.1	4.0	3.3	4.7	[illegible]
Elgin, Joliet & Eastern	70	51	65	31	29	49	197	145	189	106	49	148	[illegible]	1.7	[illegible].1	1.0	1.[illegible]	1.6
Illinois Terminal	91	90	72	84	78	83	225	223	187	225	226	219	3.0	2.5	2.3	2.7	[illegible].4	2.7
Long Island	87	115	103	82	84	94	340	348	358	355	338	348	3.0	4.0	[illegible]	[illegible]	[illegible]	3.3
Missouri-Illinois	173	194	128	194	41	146	392	438	327	491	113	352	5.5	[illegible]	4.1	6.2	1.3	4.7
Pennsylvania	86	89	80	[illegible]4	94	89	271	[illegible]78	[illegible]	351	[illegible]7	305	3.0	3.1	2.8	3.[illegible]	[illegible]	3.1
Penna.-Reading Seashore Lines	77	64	61	101	69	78	382	245	235	442	402	322	2.8	[illegible]	[illegible].2	[illegible].7	[illegible]	[illegible]
Reading Co.	65	88	68	43	77	72	210	290	274	162	290	246	2.[illegible]	3.[illegible]	.2	1.5	[illegible].8	[illegible].6
Staten Island Rapid Transit	63	59	45	45	71	57	217	208	167	140	215	191	[illegible]	2.3	1.7	1.7	2.5	[illegible].2
Western Maryland	61	72	75	76	76	72	191	223	261	277	[illegible]02	2[illegible]3	2.1	[illegible]	[illegible].6	2.[illegible]	2.[illegible]	[illegible]
Total	73	91	83	78	76	80	224	275	265	281	280	265	[illegible]	3.2	[illegible]	[illegible].7	2.6	[illegible]
POCAHONTAS REGION:																		
Atlantic & Danville 2	20	118	115	140	89	96	45	276	278	390	249	248	0.7	4.[illegible]	[illegible].9	4.0	[illegible].1	[illegible].1
Chesapeake & Ohio (incl. Pere M.)	77	81	80	80	79	79	224	217	250	274	276	248	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Norfolk & Western	125	137	130	124	115	126	351	373	383	411	370	376	4.0	[illegible]	[illegible]	4.0	[illegible].7	4.[illegible]
Richmond, Fred'burg & Potomac	44	47	81	89	97	72	130	138	270	313	161	242	1.5	1.[illegible]	2.[illegible]	[illegible].0	[illegible]	[illegible]
Virginian	121	114	142	117	114	122	310	301	397	365	74	349	3.9	3.7	4.6	3.8	[illegible].7	[illegible]
Total	93	101	100	97	93	97	264	270	302	326	314	295	3.0	[illegible]	[illegible]	[illegible]	[illegible].1	
SOUTHERN REGION:																		
Alabama Great Southern	177	147	100	[illegible]3	80	119	569	470	359	354	[illegible]52	405	5.8	4.8	[illegible]	3.1	[illegible].6	[illegible]
Atlanta & St. Andrews Bay	146	172	161	146	110	147	440	584	624	631	467	552	4.8	5.[illegible]	5.[illegible]	4.8	[illegible].6	4.[illegible]
Atlanta & West Point	153	160	158	17[illegible]	169	162	441	489	515	557	[illegible]13	523	5.1	5.3	[illegible]	5.8	[illegible].7	5.4
Atlantic Coast Line (incl. AB&C)	141	99	107	151	153	130	377	261	354	541	517	410	4.6	3.2	[illegible].5	4.9	4.9	4.2
Central of Georgia	136	132	1[illegible]3	1[illegible]0	100	131	399	293	34[illegible]	371	306	343	4.4	4.6	[illegible].3	4.5	[illegible]	4.[illegible]
Charleston & Western Carolina	157	208	235	216	191	201	468	552	917	765	762	679	[illegible].4	7.[illegible]	7.[illegible]	7.5	6.[illegible]	[illegible]
Cincinnati, New Orleans & Tex. Pac.	178	161	137	107	97	136	570	51[illegible]	465	[illegible]39	[illegible]63	460	6.0	5.4	[illegible].6	[illegible].6	[illegible]	[illegible]
Clinchfield	284	286	310	266	477	341	693	806	976	1160	1487	1025	9.3	9.4	[illegible].9	11.[illegible]	14.[illegible]	10.9
Columbus & Greenville	163	143	139	88	98	126	366	311	319	221	249	293	5.2	4.[illegible]	4.4	2.9	[illegible].1	4.[illegible]
Florida East Coast	136	133	117	130	134	134	389	391	403	541	450	443	4.7	4.[illegible]	4.0	[illegible].2	[illegible]	[illegible]
Georgia R.R.	128	145	160	163	162	152	[illegible]49	390	482	[illegible]	[illegible]41	4[illegible]7	4.[illegible]	4.[illegible]	[illegible]	[illegible].4	[illegible]	[illegible]
Georgia & Florida	225	248	314	263	250	260	[illegible]71	340	456	[illegible]82	623	466	8.[illegible]	[illegible]	[illegible]	[illegible].7	[illegible]	[illegible]
Georgia Southern & Florida	204	211	214	190	165	198	463	487	534	613	[illegible]58	537	6.[illegible]	6.[illegible]	[illegible]	6.[illegible]	[illegible].4	[illegible]
Gulf, Mobile & Ohio (incl. Alton)	135	122	106	138	131	126	344	318	293	409	406	354	4.3	[illegible].9	[illegible].4	1.4	4.1	4.0
Illinois Central (incl. GASI and Y&MV)	157	144	145	128	101	135	420	389	374	378	419	376	5.[illegible]	4.7	[illegible]	4.[illegible]	[illegible]	4.4
Louisville & Nashville	104	100	118	131	128	116	272	259	219	277	292	324	3.6	3.[illegible]	[illegible].1	4.[illegible]	4.[illegible]	4.[illegible]
Mississippi Central	168	103	135	174	215	159	308	245	443	493	668	411	5.3	[illegible]	4.[illegible]	5.[illegible]	[illegible]	[illegible]
Nashville, Chattanooga & St. Louis	99	1[illegible]6	159	162	150	141	246	333	4[illegible]1	477	49[illegible]	394	3.6	5.0	5.[illegible]	[illegible]	[illegible]	[illegible]
New Orleans & Northeastern	198	141	92	76	67	115	661	470	309	287	262	398	6.7	4.8	3.1	[illegible]	[illegible]	[illegible]
Norfolk Southern	201	210	166	236	240	211	409	444	3[illegible]7	551	592	477	6.9	7.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Seaboard Air Line	161	148	127	104	72	122	427	278	287	3[illegible]	24[illegible]	356	[illegible]	4.9	[illegible]	[illegible]	[illegible]	4.1
Southern Ry.	89	111	102	86	82	94	268	335	328	302	29[illegible]	306	[illegible].9	[illegible]	3.3	[illegible]	[illegible]	[illegible]
Tennessee Central	130	136	132	115	110	12[illegible]	194	315	319	347	3[illegible]	30[illegible]	4.0	4.[illegible]	4.[illegible]	[illegible]	[illegible].6	4.1
Western Ry. of Alabama	127	162	165	199	168	168	367	495	611	645	609	545	4.[illegible]	5.4	[illegible]	6.[illegible]	5.[illegible]	
Total	136	129	129	130	118	128	261	343	367	411	356	374	4.[illegible]	4.[illegible]	4.[illegible]	4.3	[illegible]	4.[illegible]

Table B

NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOOD CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1949 to 1953, inclusive

Note: All figures are exclusive of bridge and switch ties

Table B

NUMBER AND AGGREGATE COST OF NEW WOOD CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF NEW WOOD CROSS TIE RENEWALS TO TOTAL CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1949 to 1953, inclusive

Note: All figures are exclusive of bridge and switch ties

Road	Number of new wood cross tie renewals per mile of maintained track						Aggregate cost of new wood cross tie renewals per mile of maintained track						Per cent new wood cross tie renewals to all ties in tracks					
	1949	1950	1951	1952	1953	5 year average	1949	1950	1951	1952	1953	5 year average	1949	1950	1951	1952	1953	5 year average
NORTHWESTERN REGION:																		
Chicago & North Western	73	90	88	68	77	79	$184	$229	$228	$206	$265	$222	2.5	3.0	[illegible]	2.3	[illegible]	[illegible]
Chicago Great Western	204	217	68	100	75	133	690	744	238	382	297	470	6.9	7.3	2.3	3.3	[illegible]	[illegible]
Chicago, Milwaukee, St. Paul & Pacific	64	23	35	50	64	47	169	55	77	148	175	125	2.1	0.7	1.1	1.6	1.1	[illegible]
Chicago, St. Paul, Minpls. & Omaha	80	89	84	57	76	77	228	253	251	183	278	239	2.7	3.0	2.6	1.9	2.6	[illegible]
Duluth, Missabe & Iron Range	94	60	46	55	67	64	243	170	133	170	218	187	3.2	2.0	1.7	2.0	2.2	2.2
Duluth, South Shore & Atlantic	162	156	122	116	185	148	408	384	321	335	593	408	5.4	5.2	4.1	3.9	3.4	5.0
Duluth, Winnipeg & Pacific	222	173	125	98	75	139	513	420	312	246	211	340	7.5	5.9	4.2	3.3	2.6	4.7
Great Northern	118	96	108	91	89	100	314	282	328	310	331	313	3.8	3.1	3.5	2.9	2.9	3.2
Green Bay & Western	120	109	108	109	192	128	375	316	386	402	679	432	4.2	3.8	3.8	[illegible]	5.7	[illegible]
Lake Superior & Ishpeming	137	112	107	86	77	104	284	220	226	197	209	227	4.6	3.7	2.6	2.9	2.5	[illegible]
Minneapolis & St. Louis	196	190	153	178	165	176	476	468	390	468	488	464	6.5	6.3	5.2	[illegible]	5.5	[illegible]
Minpls., St. Paul & S.S. Marie (incl. Wis. C)	97	98	97	98	101	98	234	236	245	336	346	279	3.2	3.3	3.3	3.3	3.4	3.3
Northern Pacific	62	49	52	53	54	54	153	131	140	154	180	152	2.1	1.7	1.8	1.8	1.9	[illegible]
Spokane International	310	313	378	393	432	365	481	438	804	1256	1443	884	10.7	10.7	13.0	13.5	14.8	12.5
Spokane, Portland & Seattle	76	67	63	42	55	61	200	173	142	161	211	177	2.5	2.2	2.0	1.3	1.7	1.9
Total	90	77	75	73	79	79	235	207	203	229	263	227	3.0	2.6	2.5	2.4	2.6	2.6
CENTRAL WESTERN REGION:																		
Atchison, Topeka & Santa Fe	70	60	61	64	68	65	185	167	177	186	211	185	2.2	1.9	1.9	2.0	2.1	2.0
Chicago, Burlington & Quincy	64	63	58	48	58	58	166	170	161	141	195	167	2.1	2.1	1.9	1.5	1.9	1.9
Chicago, Rock Island & Pacific	84	88	82	85	81	84	199	202	206	226	218	210	2.8	3.0	2.8	2.8	2.7	2.3
Colorado & Southern	68	59	55	53	67	60	201	170	165	175	224	187	2.3	2.0	1.8	1.8	2.2	2.0
Colorado & Wyoming	40	38	153	82	29	68	127	78	773	389	109	295	1.4	1.3	5.2	2.7	0.9	2.3
Denver & Rio Grande West. (incl. D&SL)	56	60	60	61	79	63	195	199	211	236	327	234	1.8	1.9	1.9	2.0	2.5	2.0
Fort Worth & Denver	73	64	63	88	71	72	203	184	197	261	225	214	2.5	2.1	2.1	2.9	2.4	2.4
Northwestern Pacific	185	175	196	215	245	203	473	431	602	702	802	602	6.4	6.0	6.8	7.4	8.5	[illegible]
Sacramento Northern	112	68	62	49	57	70	279	184	180	165	196	201	3.7	[illegible]	2.1	1.6	1.9	[illegible]
Southern Pacific Co. - Pac. Lines	75	72	72	78	74	74	207	192	231	269	248	229	2.4	2.4	2.4	2.6	[illegible]	2.5
Toledo, Peoria & Western	38	92	64	78	88	72	89	202	209	267	306	215	1.2	2.9	2.0	2.5	2.8	2.3
Union Pacific	64	70	40	77	73	65	174	181	120	264	252	198	2.3	2.5	1.4	2.7	2.6	2.3
Utah Ry.	139	52	19	33	23	53	402	184	60	136	89	176	5.0	1.9	0.7	1.2	0.8	1.9
Western Pacific	208	144	123	142	142	151	593	388	373	562	567	497	7.0	4.9	4.1	4.8	4.8	5.1
Total	74	70	64	71	73	70	196	187	186	226	239	207	2.4	2.3	2.1	2.4	2.4	2.3
SOUTHWESTERN REGION:																		
Beaumont, Sour Lake & Western	188	150	137	146	174	159	533	399	407	418	512	454	4.8	5.0	4.6	4.9	5.8	5.0
International-Great Northern	124	178	201	203	176	176	352	441	571	561	513	488	4.2	[illegible]	6.4	6.4	5.6	5.6
Kansas City Southern	56	76	154	192	182	132	148	192	434	561	582	383	1.8	2.4	4.5	6.1	5.8	4.2
Kansas, Oklahoma & Gulf	102	94	105	150	134	117	274	245	357	450	400	345	3.4	3.2	3.5	5.0	4.5	3.9
Louisiana & Arkansas	45	120	130	210	137	128	105	290	367	589	422	355	1.4	3.7	4.0	6.4	4.2	3.9
Midland Valley	79	85	78	89	82	83	199	212	245	248	237	228	2.7	2.9	2.6	3.0	2.8	2.8
Missouri-Kansas-Texas Lines	79	96	76	116	128	99	214	257	217	331	357	275	2.5	3.1	2.4	3.7	4.0	3.1
Missouri Pacific	102	140	142	140	122	129	246	350	396	413	368	355	3.3	4.5	4.6	4.5	3.9	4.2
New Orleans, Texas & Mexico	144	188	221	228	185	193	410	495	658	655	545	553	4.7	6.1	7.2	7.4	6.0	6.3
Oklahoma City-Ada-Atoka	193	189	130	169	134	163	465	490	439	415	388	440	6.7	6.6	4.5	5.9	4.7	5.7
St. Louis, Brownsville & Mexico	105	113	118	124	138	120	294	272	331	390	392	336	3.5	3.7	3.9	4.1	4.6	4.0
St. Louis-San Francisco	127	127	91	114	81	108	299	316	243	328	232	284	4.0	4.0	2.9	3.6	2.6	3.4
St. Louis, San Francisco & Texas	118	111	83	105	98	103	284	280	233	282	278	271	3.8	3.5	2.7	3.4	3.1	3.3
St. Louis Southwestern Lines	143	134	140	110	149	135	377	339	374	320	437	369	4.6	4.3	4.5	3.5	4.8	4.3
San Antonio, Uvalde & Gulf	108	112	121	161	150	130	269	276	340	438	425	350	3.7	3.9	4.2	5.6	5.3	4.5
Texas & New Orleans	108	110	95	124	106	109	271	269	234	317	276	273	3.9	4.0	3.4	4.5	3.8	3.9
Texas & Northern	124	64	192	204	136	144	217	113	507	569	390	359	3.1	1.6	5.0	5.5	3.6	3.8
Texas & Pacific	146	139	145	140	139	142	394	326	401	368	396	377	5.0	4.8	5.0	4.8	4.8	4.9
Texas Mexican	75	100	184	133	99	118	176	291	627	453	323	374	2.4	3.2	5.8	4.2	3.1	3.7
Total	108	124	119	135	121	121	273	310	329	383	351	329	3.6	4.1	3.9	4.4	4.0	4.0
Grand total, United States	91	92	87	91	90	90	249	252	257	296	300	271	3.0	3.0	2.9	3.0	3.0	3.0
CANADIAN ROADS:																		
Canadian National	142	145	131	135	139	138	295	306	302	357	406	333	4.8	5.0	4.5	4.6	4.8	4.7
Canadian Pacific	143	134	131	131	128	133	329	313	301	344	407	338	5.0	4.7	[illegible]	4.5	4.4	4.6
Ontario Northland	273	272	297	284	322	290	524	588	626	874	1286	780	9.6	9.6	10.3	9.8	11.1	10.1

* Not reported.

a The Atlantic & Danville became a Class I road August 1, 1949; figures shown for 1949 are for the last five months of year.

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Advance Report of Committee 15—Iron and Steel Structures

Assignment 4

Stress Distribution in Bridge Frames

(a) Floorbeam Hangers

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Comparative Test of a Structural Joint Connected with High-Strength Bolts and a Structural Joint Connected with Rivets and High-Strength Bolts

By J. W. Carter[1], J. C. McCalley[2] and L. T. Wyly[3]

FOREWORD

The research project on stresses in bridge frames consists of the investigation of the causes and remedies for fatigue failures in floorbeam hangers in railway bridges and in the counterweight trusses of heel-trunnion bascule bridges. It is being conducted at the Purdue University Engineering Experiment Station under the direction of L. T. Wyly, research professor of structural engineering and head of department. Administration is by the director of the Engineering Experiment Station and dean of engineering, and by the head of the School of Civil Engineering and Engineering Mechanics. In June 1953, Dr. A. A. Potter retired as director of the Engineering Experiment Station and dean of engineering and was succeeded by Dr. G. A. Hawkins. In June 1954, Professor R. B. Wiley retired as head of the School of Civil Engineering and Engineering Mechanics and was succeeded by Professor K. B. Woods as head of the School of Civil Engineering. The program is sponsored financially by the Association of American Railroads. It was initiated upon the recommendation of AREA Committee 15—Iron and Steel Structures, and is supervised by the Subcommittee on Stress Distribution in Bridge Frames. This is a cooperative project, and the research staff of the Association of American Railroads, under the general direction of G. M. Magee, director of engineering research, and E. J. Ruble, research engineer structures, assists in and advises regarding the work.

INTRODUCTION

At a meeting of AREA Committee 15 at Lafayette, Ind., on November 3, 1948, the Purdue University staff members working on the project traced the floorbeam hanger fatigue failures in riveted members to high local stress and strain concentrations at rivet holes associated with high rivet bearing and proposed the replacement of rivets by high-strength bolts in drilled or reamed holes as a remedy. This view was subsequently amplified at the AREA convention in March 1949 and in the progress report on Assign-

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[2] Junior engineer Modjeski & Masters, formerly research associate in structural engineering, Purdue University.

[3] Research professor of structural engineering and head of department, Purdue University.

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ment 4 published in AREA Bulletin 485 in January 1950. Much confirming research has since been done on this thesis by the Purdue staff and reported to the committee. It was considered desirable to make a static test of a full-scale connection of a hanger to the upper chord gussets where high-strength bolts were used in the two lowest lines of rivets in the lower edge of the gussets in order to ascertain the stress, strain and slip distribution in the member and in the gussets in such a joint, and also to determine if the bolts and rivets would work together. It was also considered desirable to test a similar joint connected with high-strength bolts in all holes. The data on this last test could then be compared with data on similar riveted members.

Early in 1951, after C. H. Sandberg had secured written approval of the proposed test program by members of AREA Committee 15, fabrication of the test models was begun. The bolted joint was tested by Dr. J. W. Carter in 1952, and a preliminary report was presented at the ASCE Centennial meeting in September of that year at Chicago. Copies of this report were sent to all members of Committee 15 at that time. The riveted and bolted joint was tested by J. C. McCalley in 1954. The joints were tested in the 600,000-lb testing machine in the structural testing laboratory at Purdue University.

DIGEST

The test under static loads of two full-scale joints representing the connections of a floorbeam hanger to the upper chord gussets of a railway bridge is reported in this paper. One joint was connected by rivets except that high-strength bolts were used in the two lowest lines of holes in the gussets. The other joint was connected entirely by high-strength bolts. Photographs of the joints under test in the structural testing laboratory at Purdue University are shown in Figs. 1, 2, and 3. Structural details are shown in Fig. 4. The instrumental set-up is given in Figs. 5, 6, 7, and 8. Figs. 10, 11, 12 show the loading sequence used. (Note: All figures are present at end of report).

The principal findings are as follows:

1. Neither joint showed any significant slip for axial stresses below the design stresses. (See Fig. 13.)

2. The first major slip in both the bolted joint and the riveted and bolted joint occurred when the elastic limit of the main material had been reached in axial stress. (See Figs. 9, 13, 16, and 17.)

3. When the main hanger material reached the elastic limit on the gross area, about 32 ksi in these members, the reduction in the thickness of the flange as the metal stretched produced an appreciable loss in clamping force, and this allowed the first major slip to occur. (See Figs. 16 and 17.)

4. Since the first major slips are thus correllated with the loss in clamping force consequent upon the main material reaching the elastic limit of about 32 ksi, it is entirely possible that if steel of a higher elastic limit had been used the bolts might have developed a higher load at first major slip. (See Figs. 16 and 17.)

5. After major slips had occurred and the main material had come to bear on the bolts, the clamping force in the bolts rose rapidly, apparently as a result of shear combined with clamping force in the bolt, and this rise continued with increasing load on the hanger. (See Figs. 16 and 17.)

6. For axial stresses between the design stress and the elastic limit of the material the bolted joint showed less than half as much slip as the riveted and bolted joint, and the riveted and bolted joint showed somewhat less slip than a similar joint fully riveted would be expected to show as indicated by other test data. (See Figs. 13 and 14.)

7. In both joints, at any given load producing stresses below the yield point in the hanger, the slips are largest at the ends of the connection and the slips at the center of the connection are smallest. Both joints show, however, the same general shape of slip distribution graph. (See Figs. 20 to 23, incl.)

8. It is thus plain that slip in a riveted or a bolted joint is a highly local matter. Readjustment of load between the component parts of the joint takes place by means of a series of local slips. (See Figs. 20 to 23, incl.)

9. It is suggested that a rational design of the bolted connection should be based on knowledge of the magnitude of the local friction and the manner in which it acts.

10. The capacity of the testing machine not being great enough to break the joints, the bolted joint was put under final load of 660 kips with all bolts except 16 removed. The bolts then failed partly through shear and partly through tension at a computed average unit stress of 90 ksi on the stress area. This stress was computed by dividing total load on the joint by the stress areas of the 16 bolts. The failure was accompanied by much slip, local crushing of main material and by stretching of bolts.

11. The measured stress at the middle of a wide gusset under the action of a central load is about twice the value computed on the assumption of linear stress distribution. This is due to shear deformation in the plate. (See Figs. 34, 35, and 36.)

12. Results of these tests indicate that rivets and high-strength bolts will work together satisfactorily in a structural connection when arranged as in the riveted and bolted joint here tested.

13. These tests demonstrate that when high-strength bolts are used instead of rivets in a structural connection the high local stresses and strains at the sides of the holes due to rivet bearing, especially high in single lap joints, will be eliminated. The elimination of these high stresses and strains should raise the fatigue strength.*

14. For the same reasons results of these tests are favorable to the effort to protect existing bridges against fatigue failure by replacing the rivets at the edges of the gussets by high-strength bolts.

DESCRIPTION OF THE JOINTS

Each joint is composed of two wide-flange beams 12 in by 40 lb per ft, spliced together by two large gusset plates. (See Figs. 1, 2, 3, and 4.) One joint, hereinafter called the bolted joint, was connected entirely by high-strength bolts. The other joint, hereinafter called the riveted and bolted joint, was connected by rivets, except that the first two rows of holes at the edges of the gussets, corresponding to the two lowest rows of holes in the hanger connection to the hip gussets, were connected by high-strength bolts.

The connection of the wide-flange beam to the gussets represents the connection of a full-size floorbeam hanger to the upper chord gusset. Each joint thus permits the test of two such connections: one to square gussets and one to gussets tapered at the lower ends.

INSTRUMENTATION

Total strain plus slip in the length of connection was measured by means of traversing rods and dial indicators. (See Fig. 6.)

Local slips between the beams and the gussets were measured throughout the length of the connections as well as at the edges of the gussets. Whittemore strain gages were

* Compare Study 1 and Studies 2, 2A and 3, Fig. 7A, 8, Fatigue in Riveted and Bolted Single Lap Joints, by J. W. Carter, K. H. Lenzen, L. T. Wyly, ASCE Proceedings Separate 469, August 1954

used for these readings. (See Fig. 6.) A total of 64 slip gage lines was used on the joint and 24 additional were used on the end connections of the hangers to the specimen holders where 1⅛-in bolts were used.

Strain readings were taken at close stations throughout the length of the joint on both the hanger and on the gussets. A number of rosettes were used on the gussets. (See Figs. 7 and 8.) A total of 442 SR4 gages plus 26 SR4 rosettes was used.

The high-strength bolts used in this project were ⅞ in. in diameter by 2½ in under head. Each bolt used was tested or calibrated prior to installation. In calibration tests the bolts were placed in the hydraulic testing machine, torque was applied by a torque wrench and clamping force was measured on the testing machine load dial. All high-strength bolts were equipped with two wire gages each for calibrating and for measuring clamping force throughout the test. In order to get clearance for wire gages in the bolt hole in the plate, a short length of the unthreaded shank was milled flat. Gage lead wires were carried out through four small holes drilled in the head.

The replacement of the rivets at the edges of the gussets by high-strength bolts was suggested earlier in the floorbeam hanger investigation by the authors as a method of trying to protect existing bridges against fatigue failure in these members. The design of the riveted and bolted joint was planned in order to study the distribution of stress and strain around these critical holes. Accordingly, it was thought wise to use bolts for this joint in which the friction coefficient would be constant and the clamping force would be known and could be studied during the test. For this reason it was decided to lubricate the threads of these bolts with Molykote. The procedure used was then as follows: The bolts were first tensioned until the axial load was about 50 kips and the load removed. Gages were then glued to the bolts. The gages were protected with tracing cloth and wax. The bolts were torqued to about 42 kips and load removed, and then to 40 kips and load removed, and a curve was plotted showing axial load versus average strain. The bolts were put in the joint and torqued until the axial load was 40 kips. Strain measurements were taken on the bolts throughout the test so that the clamping forces were known at all times.

Since it was desired to test the bolted joint under the same conditions of bolt installation as may be expected in practice, no lubrication was used for the bolts of this joint. The bolts were all given a proof load test in tension and the bolts showing the greatest strength were placed at the edges of the gussets where slip would occur first and be largest. It is felt that the clamping force in these bolts may be assumed as 75 percent of the clamping yield strength developed in tension alone.

A Baldwin Strain Indicator, Type L, was used for measuring strains in the SR4 gages. Switching was by means of 10-point selector switches mounted in boxes.

TEST LOADING PROCEDURE

Riveted and Bolted Joint (Bolted Joint Similar)

Stress-strain graphs for readings taken on the gross area of the WF beams at sections A–A and X–X are shown in Figs. 9 and 10. Total slip plus strain graphs, i.e. traversing rod readings, are shown in Figs. 11 and 12 for both joints.

The specimen was loaded slowly up to 16 ksi on the gross area, or 19.4 ksi on the net area of the hanger section, complete strain readings being taken at each increment of 4 ksi, and slip readings taken all around. (See Figs. 10, 11, and 12.)

The specimen was then cycled 110 times between 3 ksi and 16 ksi on the gross area and all instruments read; no significant strain or slip was found.

The specimen was then loaded to 20 ksi and cycled 30 times from 3 ksi to 20 ksi, and all instruments read; no significant strain or slip change was found.

The specimen was loaded slowly to 34 ksi by increments of 2 ksi, strain readings being taken at each increment. The load was then reduced to 3 ksi and the four bolts on each gage line at the end of the hanger, in the middle of the joint, were removed. These are bolts 62, 63, 77, 79, 81, 84, 85, 88. (See Fig. 5.)

The specimen was now loaded slowly by increments of 8 ksi to an axial stress of 32 ksi and beyond that by increments of 2 ksi up to the capacity of the machine, or 660 kips, giving 56 ksi on the gross area or 67.5 ksi on the net area. At 49 ksi on the gross area the wide flange beam broke through the end grips, and load was removed while this was welded up. Traversing rod readings were taken throughout the entire loading range. Slip and strain readings were carried as far into the plastic range as practicable.

At the unit stress of 56 ksi on the gross area no sign of failure had occurred in either the hanger or the joint and the test was stopped.

SUMMARY OF DESIGN AND TEST DATA

Design of Joint *Hanger Section*	*Riveted and Bolted Joint*	*Bolted Joint*
12-in WF at 40 lb/ft		
Area = $11.77\ In^2$ gross		
= $9.70\ In^2$ net (4 holes 1 in dia. deducted)		
Design load $9.70\ In^2 \times 18$ ksi, kips	175	175
No. of 7/8 in rivets required at 8.12 k	22	22
Loads to 34 ksi on WF gross area		
No. of 7/8-in rivets used	16	
No. of 7/8-in bolts used	12	28
Loads after 34 ksi on WF gross area		
No. of 7/8-in rivets used	16	
No. of 7/8-in bolts used	8	28
Test Data		
Elastic limit (See Figs. 8–11 incl.) ksi on WF gross area	32	32
Yield strength (See Figs. 8–11 incl.) ksi on WF gross area	35	34
Ultimate (See Figs. 8–11 incl.) ksi on WF gross area	56 plus	56 plus
First major slip		
Axial stress (See Fig. 13) ksi on WF gross area	32	32
Total load kips	376	376
Computed average shear load per rivet or bolt ... kips	13.4	13.4
Computed average shear load per rivet or bolt ... ksi on nominal area	22.3	22.3

DISCUSSION OF TEST RESULTS

Stress-strain graphs, drawn for sections A–A and X–X, through the WF beams outside of the gussets, are given in Figs. 9 and 10, and the loading sequence history is shown also in the latter figure. The elastic limit of the WF for the bolted joint was 32 ksi and the yield strength was 34 ksi. The elastic limit for the riveted and bolted joint was also about 32 ksi and the yield strength was 35 ksi.

Total slip plus strain measured from the gussets at the center of the joints to the WF beams just clear of the ends of the gussets, i.e., in half the length of the joint, are given in Figs. 11 and 12. (See Fig. 6 also.) These graphs measure the slip of the WF with respect to the edge of the gusset plus the elongation of the gusset.

The graph of the average slip at the ends of the square and tapered gussets is shown in Fig. 13. Each graph is the average of four readings at the square and at the tapered ends of each gusset. The graphs of the individual slip readings at the ends of the east gusset are shown in Fig. 14. These slips were obtained by correcting the Whittemore slip readings by the average of the measured strains. Thus the slip graphs are not to be regarded as exact measurements. However, it is believed that they are not seriously in error. Significant facts shown by these graphs are:

1. For stresses on the gross area up to 16 ksi the graphs for the two joints agree closely. For stresses above 16 ksi the bolted joint shows increasingly less slip than the riveted and bolted joint.
2. For these joints the first major slip begins when the elastic limit of the material in the hanger, 32 ksi, is passed.
3. It seems highly probable that at the ends of the connection, as a result of unbalance of forces acting in the adjacent hanger and gusset, small slip starts at rather low loads, and that some of this may be regarded as elastic, since it apparently is reversible upon removal of load. The small slips shown in Fig. 13 at a stress of 16 ksi on the gross area appear to be in this elastic class. Loading through 110 cycles of this stress did not appear to leave any permanent slip after removal of load.

Since the clamping force in the bolts is two or three times as great as may be expected in rivets, the slip in the riveted and bolted joint is probably somewhat less than it would have been if rivets had been used throughout the connection.

In Figs. 16 to 19 are plotted the graphs comparing, at individual bolts, the measured strain in the WF beam hanger, the clamping force in the bolt, and the local slip between the gusset and the hanger. Figs. 16 and 17 are graphs at bolts at the top and bottom edges of the gussets. The authors conclude that the following sequence of events occurred:

> In these two joints when the main hanger material reached the elastic limit on the gross area, about 32 ksi here, the reduction in the thickness of the flange as the metal stretched produced an appreciable loss in clamping force, and this in turn allowed the first major slip to occur.

It is significant that the graphs in Figs. 18 and 19 at bolts at the center of the gussets, where the stresses in the WF have not passed the elastic limit, show no such large dropping off of clamping force and no such major slip occuring.

Since the first major slips are thus correllated with the loss in clamping force consequent upon the main material reaching the elastic limit of about 32 ksi, it is entirely possible that if steel of a higher elastic limit had been used the joints might have developed a higher load at first major slip.

When the slip has reached the magnitude of about 0.06 in at the end bolts in the connection the clamping force in these bolts, which had dropped to a value of less than half its initial value when the stress in the hanger reached the elastic limit, rises rapidly again. It appears that after the gusset comes to bear on the bolt on one side and the flange on the other that both shear and tension are induced in the bolt shank. (See Figs. 16 and 17). This combined stress may be expected to increase with increased load until the bolt begins to fail.

Figs. 20 to 23, incl., show the slip distribution along the length of the two joints. The following facts are of interest:

1. The bolted joint shows much less slip at all points for all axial stresses below the yield point of the hanger material than does the riveted and bolted joint.

2. In both joints, at any given load producing stresses below the yield point in the hanger, the slips are largest at the ends of the connection and the slips at the center of the connection are smallest. Both joints show, however, the same general shape of slip distribution graph.
3. It is thus plain that slip in a riveted or a bolted joint is a highly local matter. Readjustment of load between the component parts of the joint takes place by means of a series of local slips.

Comparison of these graphs with those for a test of a similar joint fully riveted would probably show greater slip for the latter, particularly at the ends of the gussets, since the clamping force in the bolts may be expected to be two or three times as great as in the rivets.

The replacement of end rivets in the joint by high-strength bolts very materially reduced the slip throughout the joint. However the precise amount of friction which is overcome to allow slip at an individual bolt at a given time is unknown. It would seem that the rational design of the bolted connection should be based on knowledge of the magnitude of this friction force and how it acts. Study of Figs. 22 and 23 for the bolted joint suggests that prior to the first major slip not all parts of the joint slipped together, i.e., the total WF did not slip with respect to the total gusset, but that ends of the gusset slipped on the WF locally.

The strain distribution along the joint is shown in Figs. 24 to 27, incl., for the riveted and bolted joint and in Figs. 28 to 31 incl. for the bolted joint. These graphs cover strains in the plastic range as well as in the elastic range.

The strain distribution in the WF hanger at three sections—in the WF just outside the gusset, and between the first and second bolts at each end of the connection—are shown for each joint in Figs. 32 to 37, incl. These graphs cover strains in the plastic as well as in the elastic range.

The capacity of the testing machine was not great enough to rupture the specimens. The bolted joint was accordingly tested by removing all but 16 high-strength bolts. These failed partly through tension and partly through shear at a unit stress of about 90 ksi on the stress area of the bolts. It should be noted that after the bolts come into bearing a very great deal of energy is absorbed by the bolted connection, in friction, in local crushing, and in tension in the bolts, before rupture occurs. After this coming into bearing a great deal of slip occurs and the bolts rotate in the holes and the clamping force, which has dropped when the elastic limit of the material of the WF was passed and when major slip has occurred, mounts rapidly again. (See Figs. 16 and 17.) Finally, the ultimate strength of the bolts under combined shear and tension is very high.

IMPLICATIONS OF TEST RESULTS REGARDING IMPACT STRENGTH OF JOINTS

These test results appear to have some implications regarding the ability of bolted joints to withstand energy loads. Comparative static and pendulum impact tests on small aluminum structural aircraft joints connected by cold driven aluminum alloy rivets have shown: (1).

1. The strength of the joint under dynamic loads varies with the amount of energy absorbed by local crushing, bending and other deformation.

(1) Impact Properties at Different Temperatures of Flush-Riveted Joints for Aircraft Manufactured by Various Riveting Methods, NACA Wartime Report, AAR 5F07, September 1945, by G. A. Maney and L. T. Wyly, Northwestern University. See Table 1 and Fig. 14(b).

2. There is very close agreement between the impact energy required to rupture a joint and the area under the load deformation graph of a static test to rupture of an identical joint.

The ability of the joint connected by high-strength bolts to absorb energy would indicate that this type ot connection should be ideal for high energy loadings.

STRAINS AND STRESSES IN GUSSETS

On the left half of the west gusset of the riveted and bolted joint a number of SR4 rosettes were placed. On the right half of the west gusset and on the east gusset uniaxial gages only were used. (See Figs. 7 and 8.) Since it was found that the stresses and strains were closely symmetrical about the longitudinal center line and also that the stresses in one gusset closely approximated those in the others for a given load on the hanger, it was decided to show the principal strains and the major principal stresses measured on the section with rosettes as typical for all sections. These graphs are given in Figs. 38 to 40, incl. A typical calculation of principal strains and stresses is given in Fig. 41.

These graphs all show that when a central load is delivered to a wide gusset plate the stress distribution along a section normal to the load axis is by no means linear but will vary somewhat as a parabola. For example, with a load on the hanger giving an axial stress of 26 ksi on the gross area of the hanger the measured principal tensile stress at the center of the gusset at section J–J is about 20.7 ksi, while at the edges of the gusset it is very small. The computed average unit stress in the gusset for this load, assuming a linear distribution, would be about 11 ksi tension. (See Fig. 39.) It is thus evident that present design procedures for gussets are unsatisfactory in important respects. This has been previously demonstrated by experiments on metal and plastic models at the University of Tennessee.(2).

IMPLICATIONS OF TEST RESULTS REGARDING FATIGUE STRENGTH OF HANGER

Since the test of these joints was planned as a study of methods proposed to help prevent fatigue failures in floorbeam hangers of existing bridges specifically, or more generally in single lap structural connections, it may be well to examine the results in the light of this aim.

It is postulated that fatigue failures in structural connections are causally connected with high local strain and stress concentrations, probably very local and in combination some times with very steep stress and strain gradients. (3). Such failures usually start at the sides of a rivet hole. The principal stress and strain concentrations at the sides of the rivet holes are probably due to:

1. The presence of the hole itself.(4)[a] (5)[a] (6)[a]
2. The bearing of the rivet on the metal in the hole.(4)[b] (5)[b]
3. The effect of slip at the end of the connection, producing over loading of the end rivets and accentuating the effects of 1 and 2 above.(4)[c]

---

(2) Experimental Investigation of Stresses in Gusset Plates by R. E. Whitmore, Bulletin No. 16, Engineering Experiment Station, The University of Tennessee. See Figs. 5–8 incl. and 21–23 incl.

(3) Report on Assignment 4. Stress Distribution in Bridge Frames—Floorbeam Hangers, by L. T. Wyly, AREA Bulletin 485, January 1950. See Figs. 22–25 incl. and Pages 28–31 incl.

(References continued at bottom of next page).

4. The highly local bearing of the rivet on the edge or contact face of the plate when slip occurs in a single lap joint and the rivet is rotated out of uniform bearing on the width of the plates. This action produces a very intense local state of stress and strain, and a very steep stress and strain gradient.(4)[d] (5)[d] (6)[d]
5. The effect of excessive straining of the metal at the sides of the hole, such as is produced by drifting holes into line in field or shop.(4)[e]
6. Any other injuries to the metal at the sides of the rivet holes, probably including punching most of all, which will open up minute cracks.

Conversely, connections free from the above high local stress and strain concentrations show a high fatigue strength.(3)[f] (4)[f]

The effects of high clamping on stress and strain in a bolted joint are:

1. The stress at the sides of the holes is compression and the strains are shortening.(3)[g] (4)[g] (5)[g]
2. The stress and strain at the sides of the hole is fairly uniform and is free from the very high local concentrations which occur with rivet or bolt bearing and no clamping.(4)[h] (5)[h]
3. Even after major slip has allowed the bolt to come to bear if the clamping is still high, the stress and strain distribution will be fairly free from high local concentrations.

The results of this investigation indicate that the performance of single lap bolted joints designed in the same way as the bolted joint tested in this investigation is favorable for the reduction of fatigue failure in new construction since:

1. The slip of the end bolts is less than the slip of end rivets. Hence the bolts should only come to bear at higher loads than for riveted joints.
2. At design or service loads major slip should not occur, and hence the bolts should not come to bear.
3. At service loads the bolts may be expected to retain their high clamping, producing a favorable stress and strain distribution in the joint.

For the same reasons the results of this investigation appear favorable for the replacement of the rivets at the ends of the gussets by high strength bolts in an attempt to protect existing structures against fatigue failures. The following precautions are necessary:

---

(4) Fatigue in Riveted and Bolted Single Lap Joints, by J. W. Carter, K. H. Lenzen, and L. T. Wyly, ASCE Proceedings Separate 469, August 1954.

(5) Stress Concentration in Built-Up Structural Members by J. W. Carter, AREA Bulletin 495, June–July 1951.

(6) AISC Engineering Conference Proceedings 1950, April 12–13.

(4)[a] Figs. 2, 3, 4. See also Refs. 3 and 4 — (5)[a] Figs. 7–12 incl. — (6)[a] Slide 12
(4)[b] Figs. 6 and 11 — (5)[b] Fig. 13
(4)[c] Fig. 9
(4)[d] Figs. 7B, 12, 7A Study 1and B, Fig. 8 — (5)[d] Fig. 19 and Table 1 — (6)[d] Slide 13
(4)[e] Figs. 7A, 8, Study 4
(3)[f] Fig. 24 (4)[f] Figs. 7A, 8, Studies 2, 2A and 3
(3)[g] Fig. 22 (4)[g] Fig. 13 (5)[g] Fig. 21
(4)[h] Fig. 15(a) (5)[h] Fig. 27 Sec. B–B

1. Avoid damage to the metal around the holes in removing present rivets.
2. Ream out the holes with a sharp reamer so the metal is smooth and unscratched and all damaged material removed.
3. Under no circumstances drift any holes.
4. Make sure that the bolts are tightened into the yield range.
5. Use carburized washers of specified size.

ACKNOWLEDGMENTS

The joints were fabricated by the Bethlehem Steel Company under a regular contract.

The authors are indebted to C. H. Sandberg and his subcommittee and to E. J. Ruble for advice and assistance in the project. Helpful advice and suggestions were also given by Kenneth Lenzen. Valuable assistance was given by the following students at Purdue University: Ralph A. McElheny, Richard LaSalle and John Ely, in the testing work and in reducing the data, and by John Dan and Richard Halbach, in drawing up the figures.

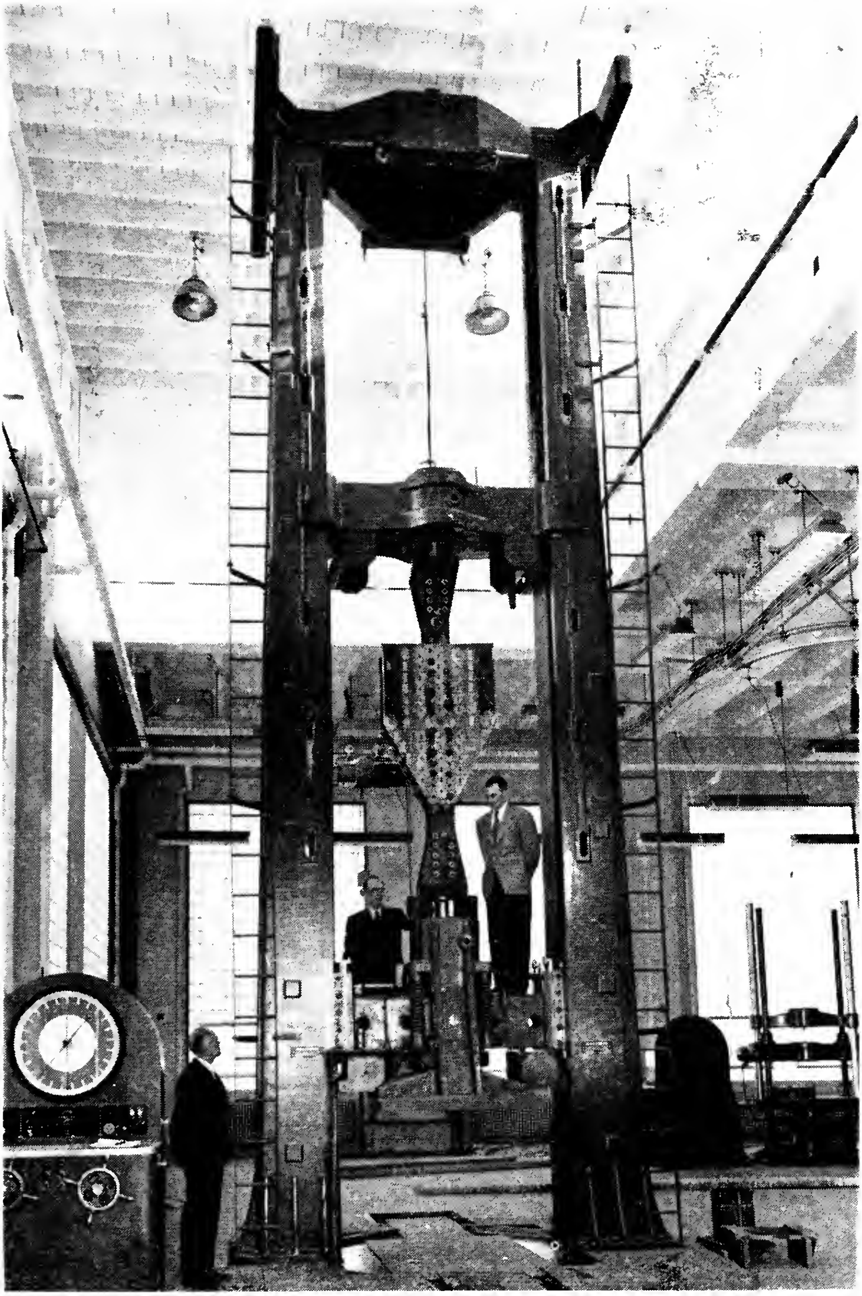


Fig. 1—Bolted joint in testing machine.

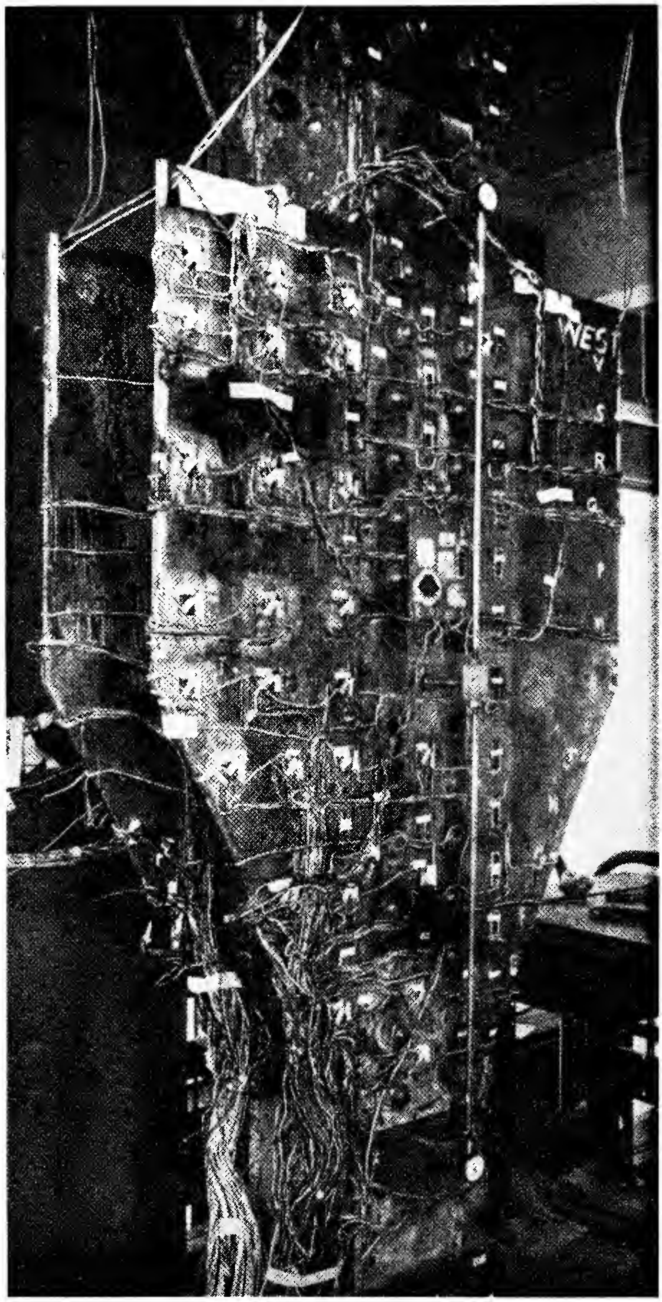


Fig. 2—Test of riveted and bolted joint—Looking east.

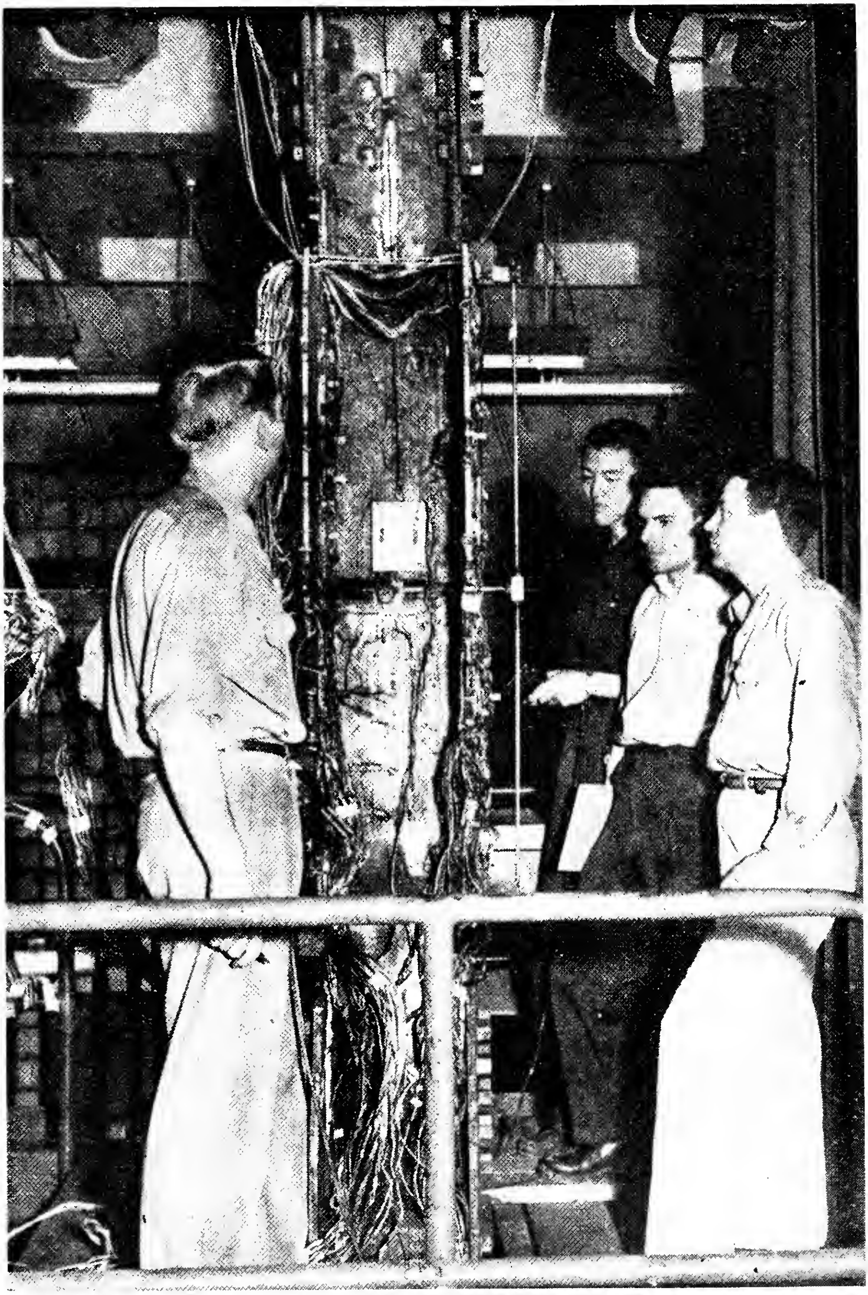
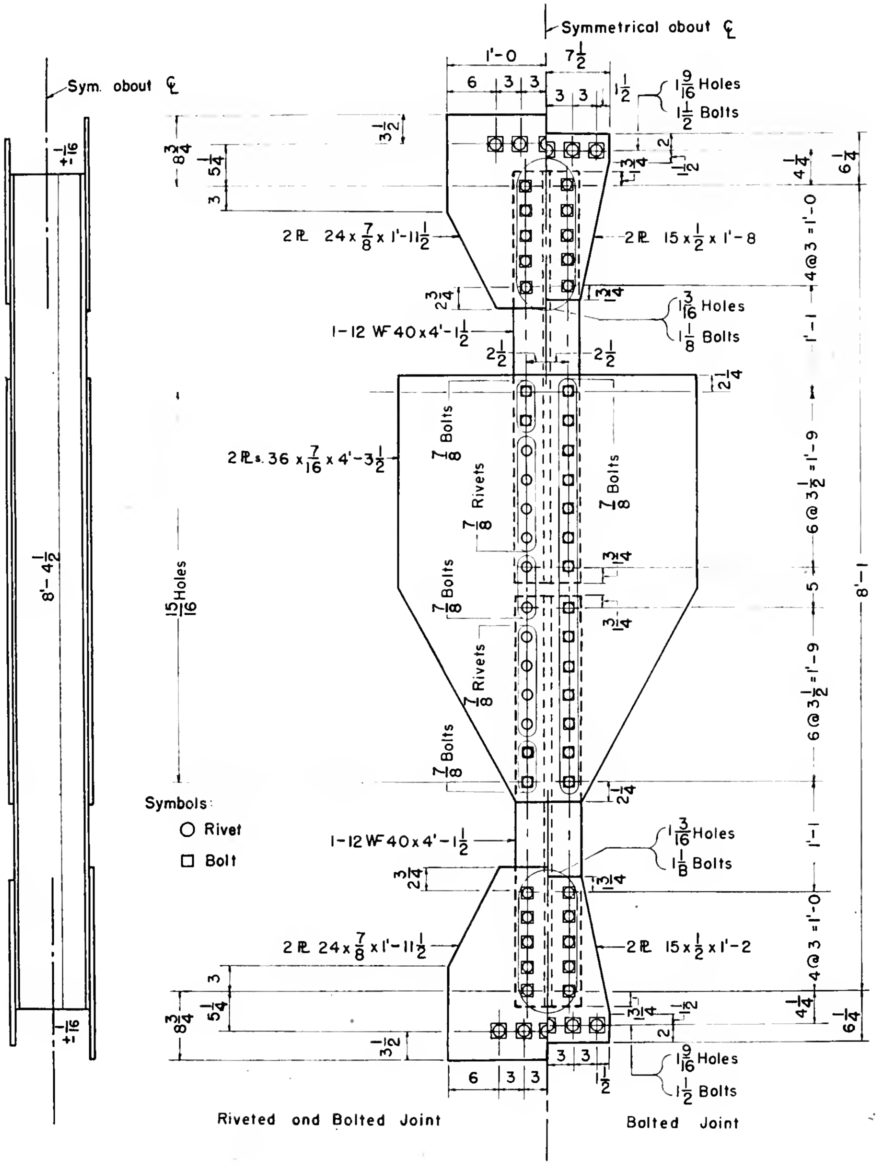


Fig. 3—Test of riveted and bolted joint—Looking south.



Notes 1 All gussets from one plate
2. All WF from one beam
3. All holes drilled
4. All bolts high strength

Mat'l spec. –
- Structural steel A.S.T.M A7-50
- Rivets A.S.T.M. A141-50
- Bolts A.S.T.M. A325-50

FIG. 4 STRUCTURAL DETAILS OF JOINTS

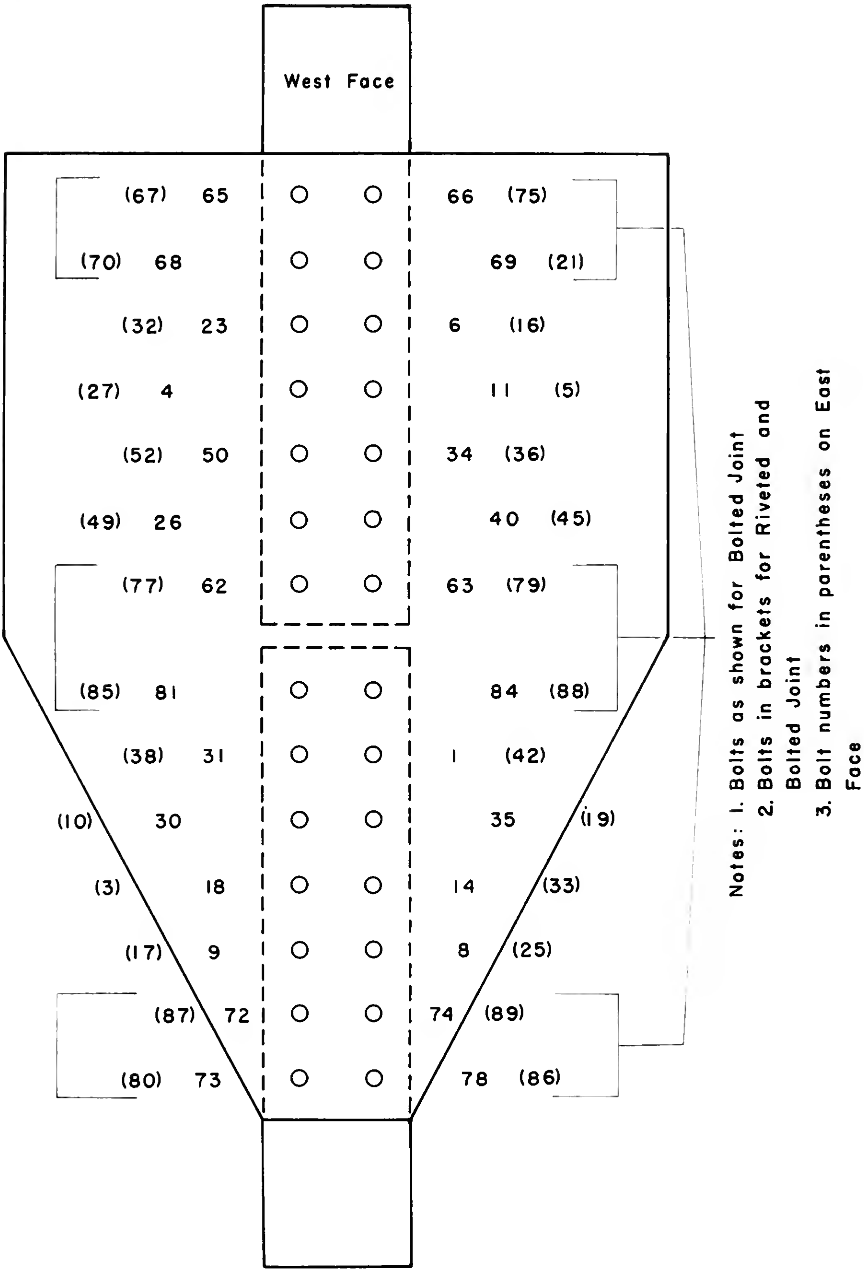


FIG 5 BOLT IDENTIFICATION DIAGRAM

Note : 1. Gage lengths located on East Face identical to West Face
2. Gage length notation on East Face indicated by prime i.e. 2a'
3. Gage lengths 10(a,b,g,h) 5(a,b,k,l) 2(a,b,w,x) are on Riveted and Bolted Joint only 2 (y, z) are on Bolted Joint only

Legend: Numbers indicate gage lengths in inches

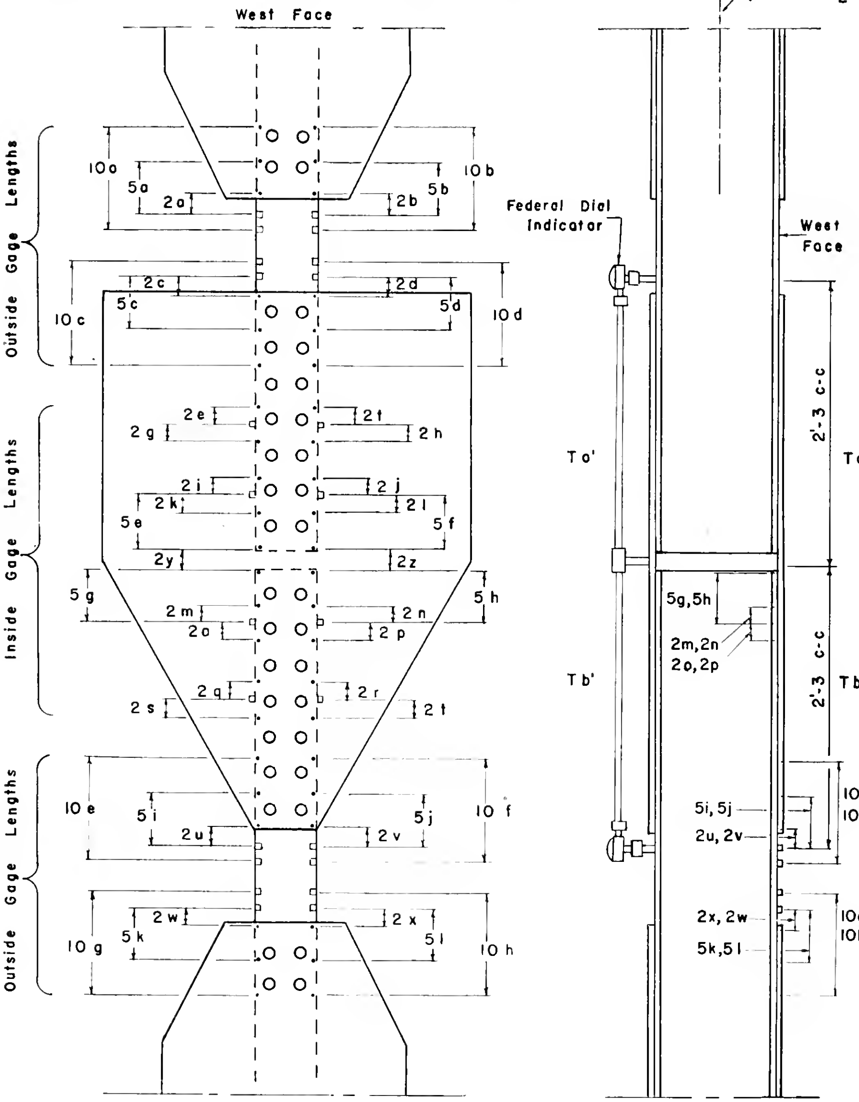
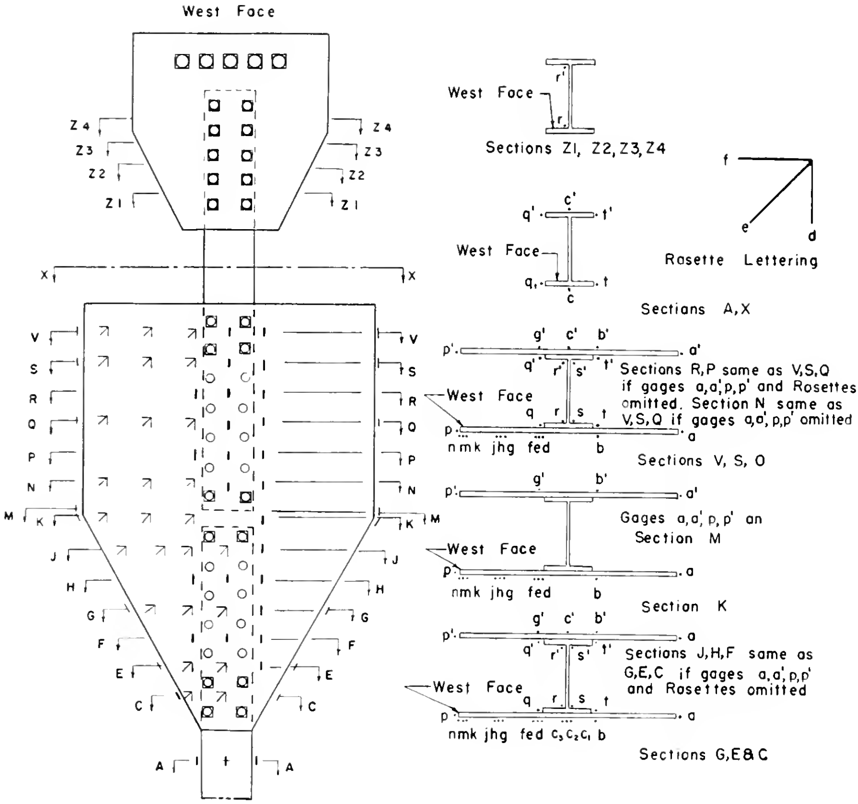


FIG. 6
LOCATION OF WHITTEMORE GAGE LENGTHS FOR SLIP MEASUREMENTS

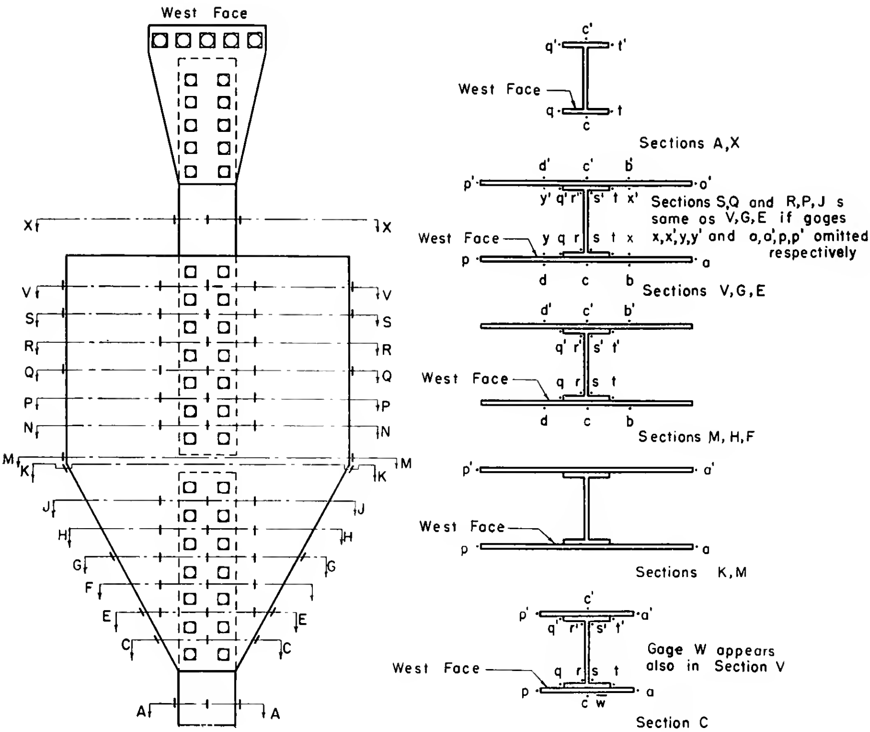
TRAVERSING RODS



Summary of SR-4 Gages Used

No Used	Type	Resistance Ohms	Location
208	A 1	120	Joint
25	AR 1	120	Joint
1	AR 7	60	Joint
48	A 7	120	Bolts

FIG. 7 SR4 IDENTIFICATION DIAGRAM - RIVETED AND BOLTED JOINT



Summary of SR-4 Gages Used

No. Used	Type	Resistance Ohms	Location
184	A1	120	Joint
48	A5	120	Joint
2	A7	120	Joint
112	A7	120	Bolts

FIG. 8 SR4 IDENTIFICATION DIAGRAM-BOLTED JOINT

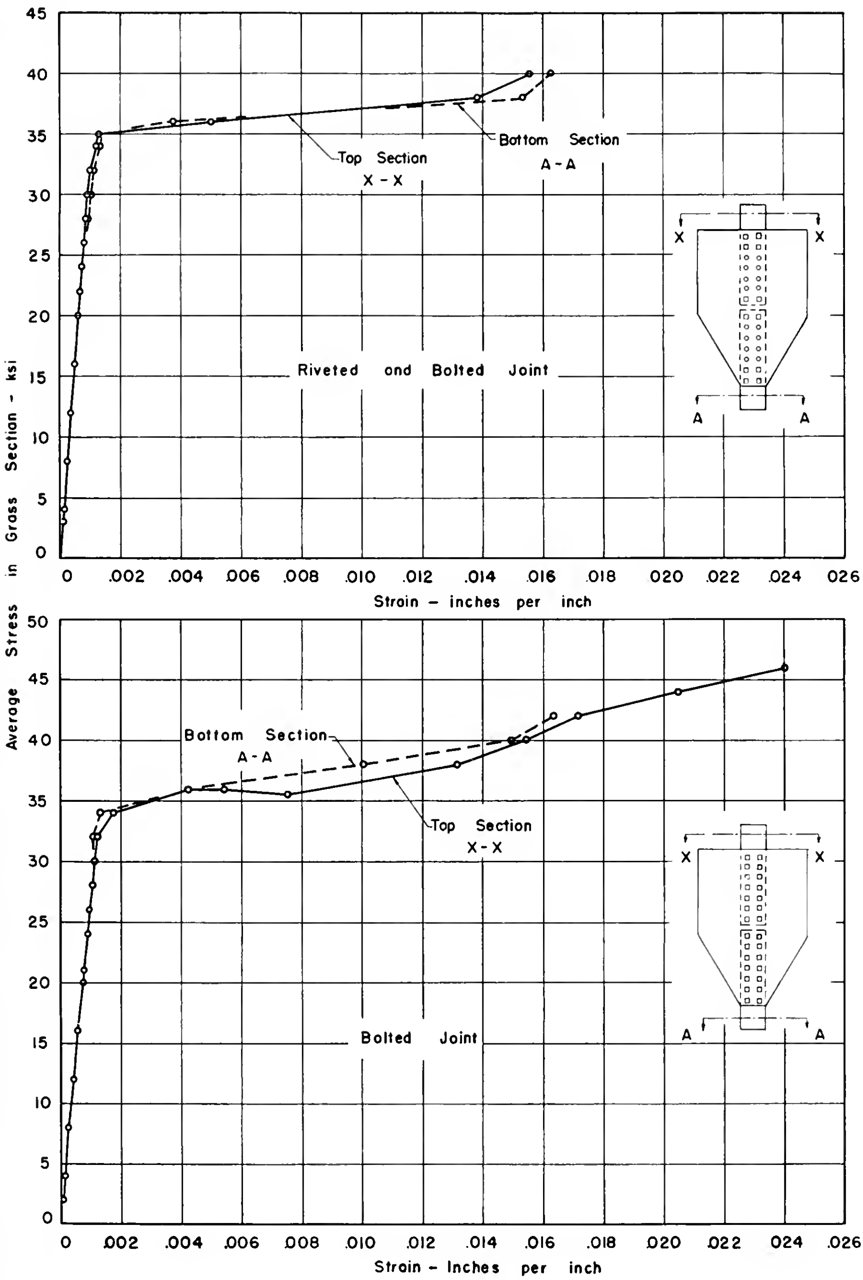


FIG 9 STRESS - STRAIN CURVES ON GROSS AREAS OF WF BEAMS
SECTIONS A-A AND X-X

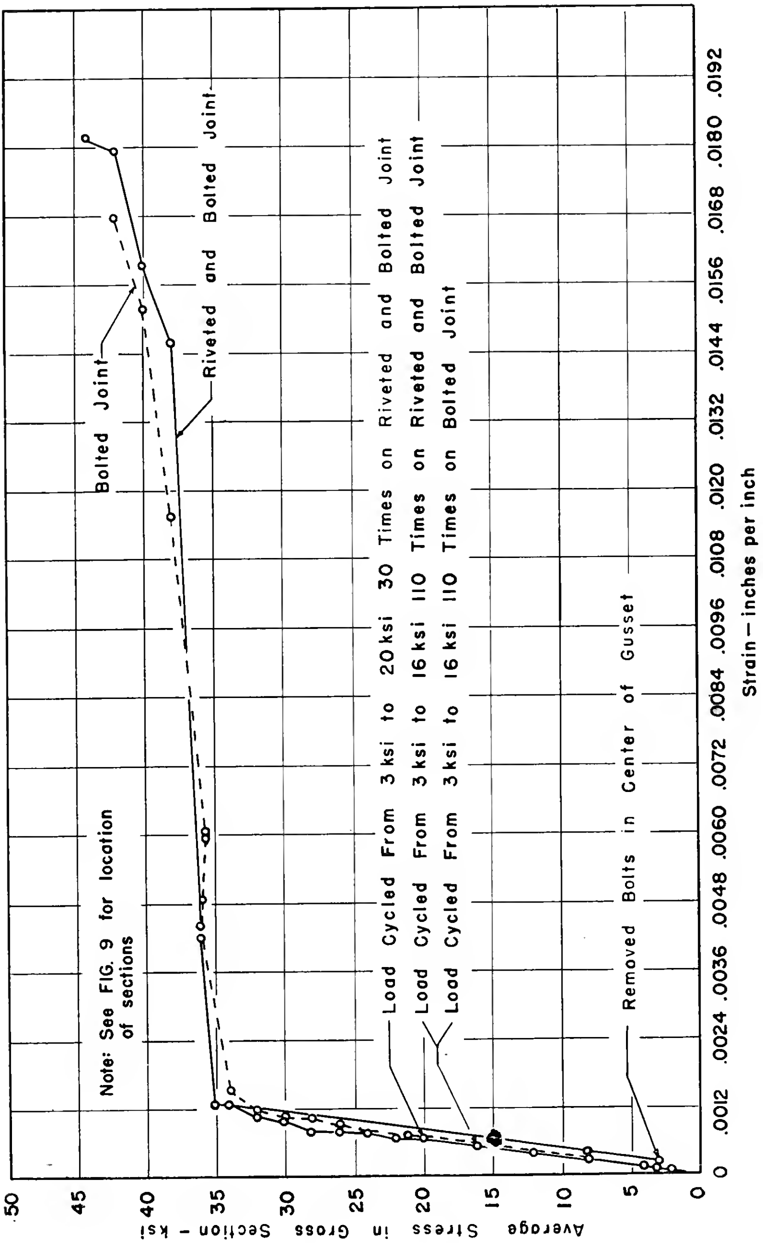


FIG. 10 STRESS-STRAIN CURVES ON GROSS AREA OF WF BEAMS
SECTIONS A-A AND X-X AVERAGED

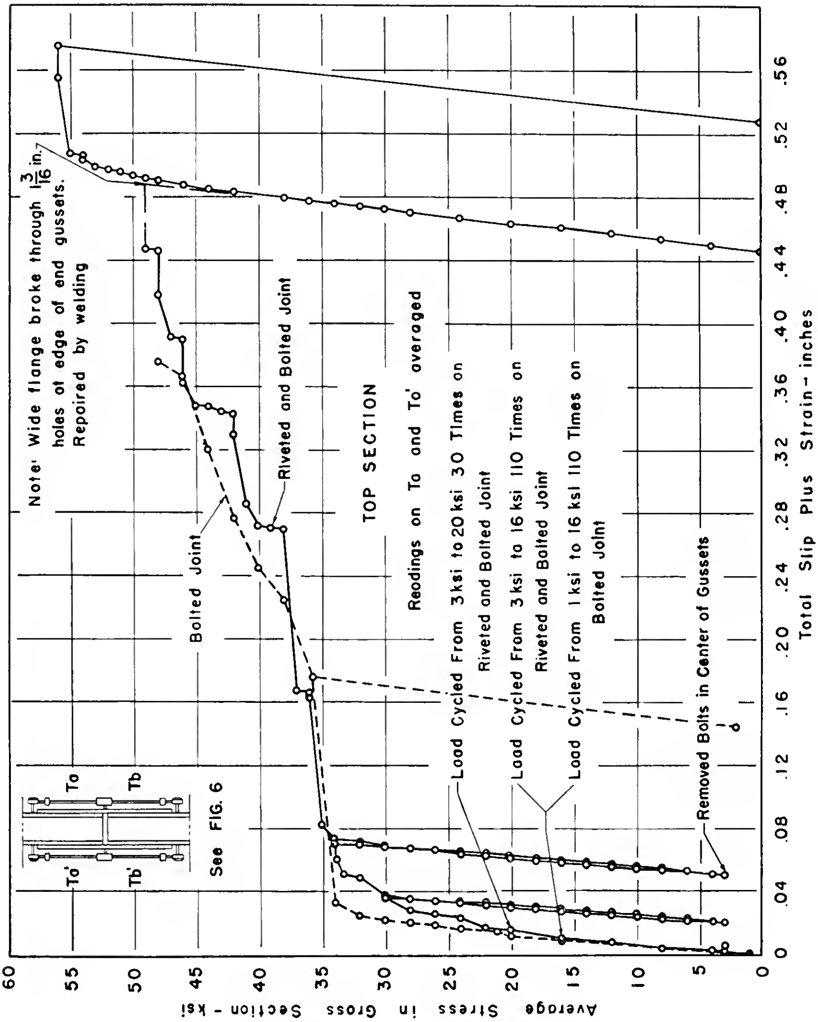


Fig. 11 TRAVERSING ROD READINGS

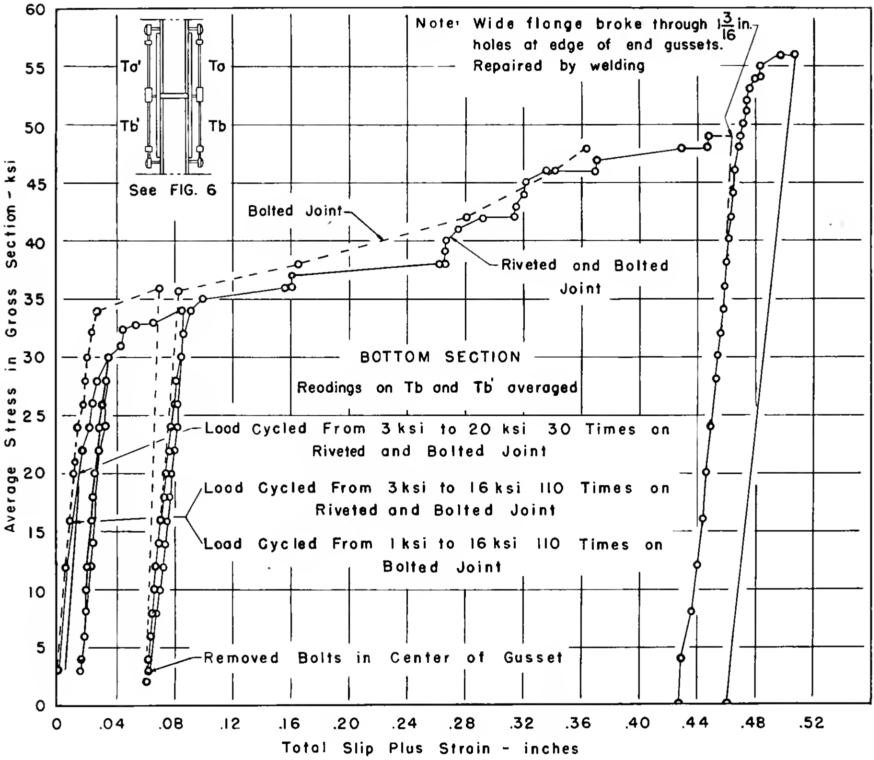


Fig. 12 TRAVERSING ROD READINGS

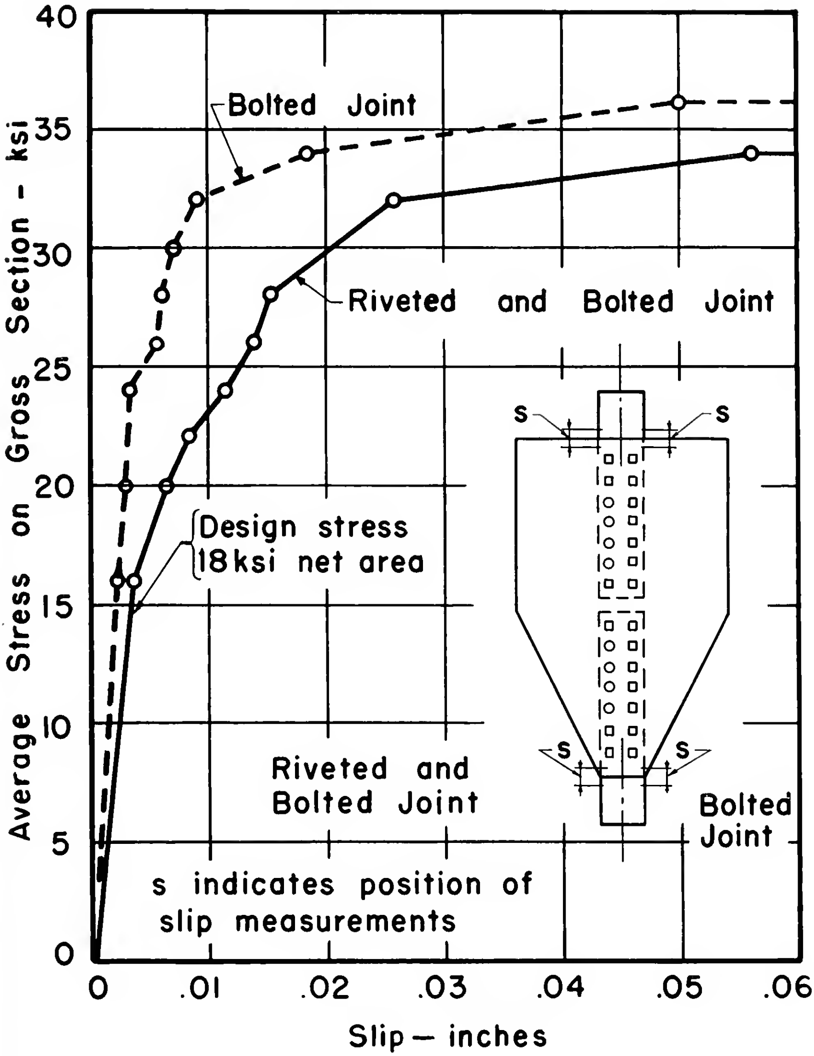


FIG. 13 SLIP AT ENDS OF GUSSET
AVERAGE OF SQUARE AND TAPERED END

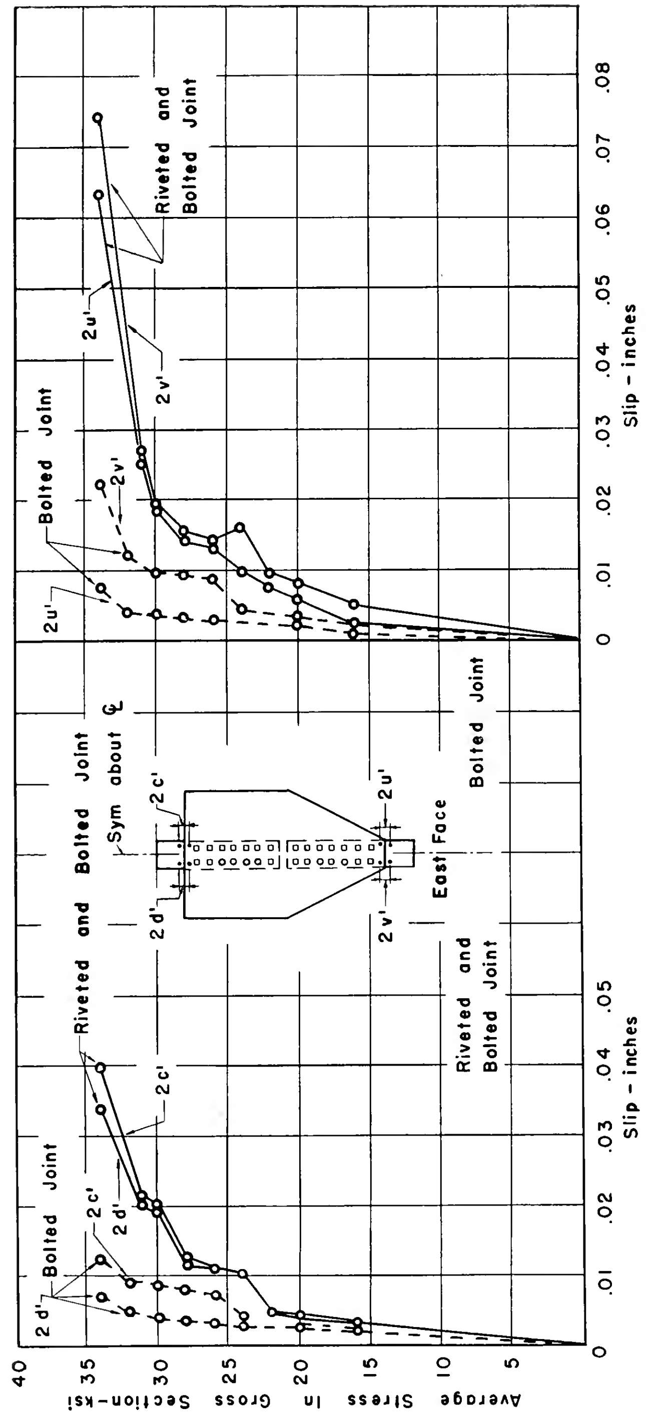


FIG. 14 SLIP AT EDGES OF EAST GUSSET

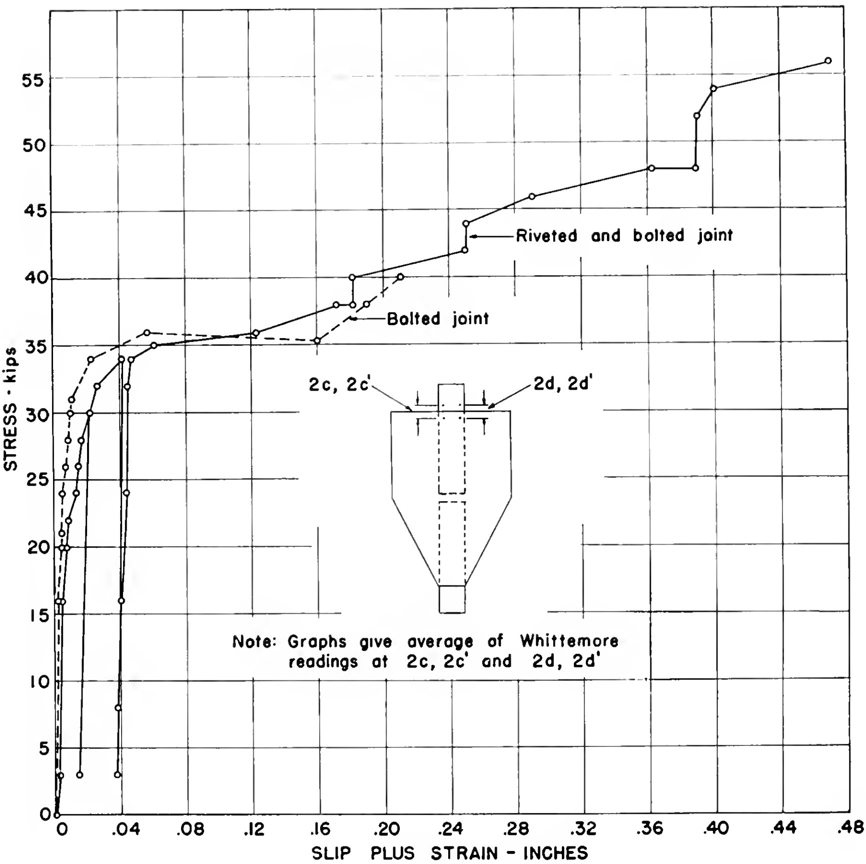


FIG. 15 AVERAGE SLIP PLUS STRAIN AT EDGE OF SQUARE GUSSET

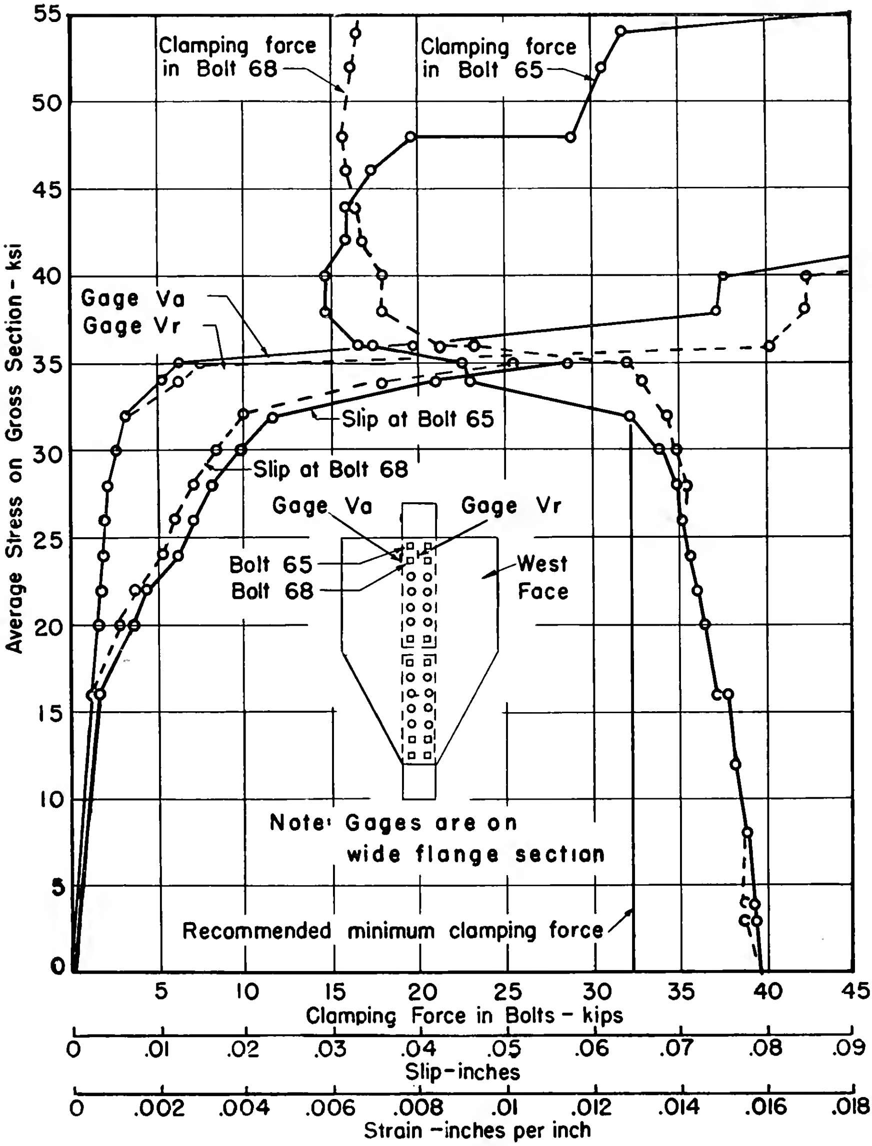


FIG. 16 CLAMPING FORCE, STRAIN AND SLIP RIVETED AND BOLTED JOINT

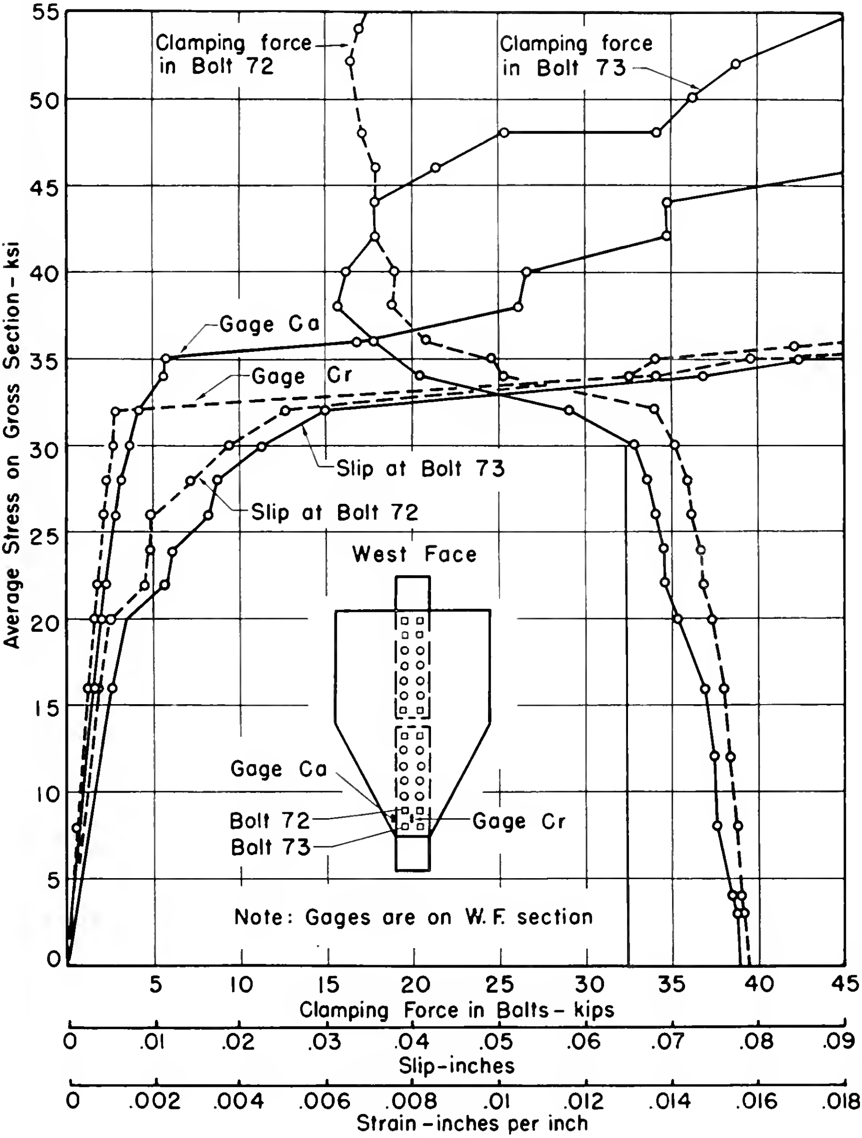


FIG. 17 CLAMPING FORCE, STRAIN AND SLIP RIVETED AND BOLTED JOINT

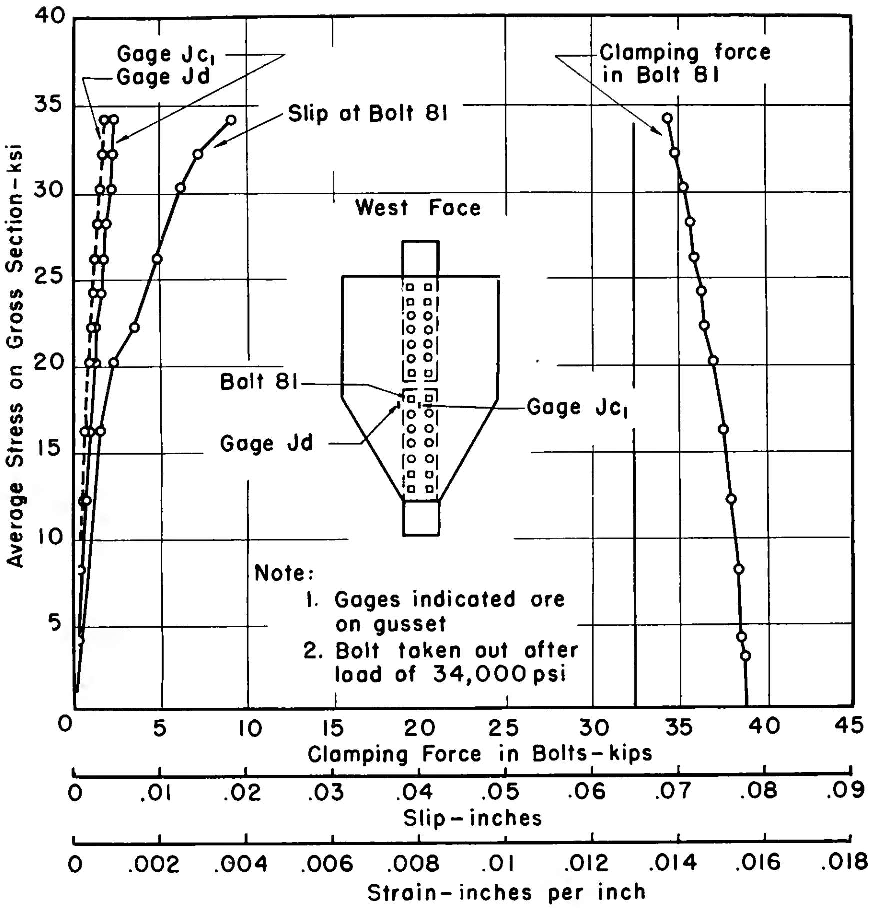


FIG. 18 CLAMPING FORCE, STRAIN AND SLIP RIVETED AND BOLTED JOINT

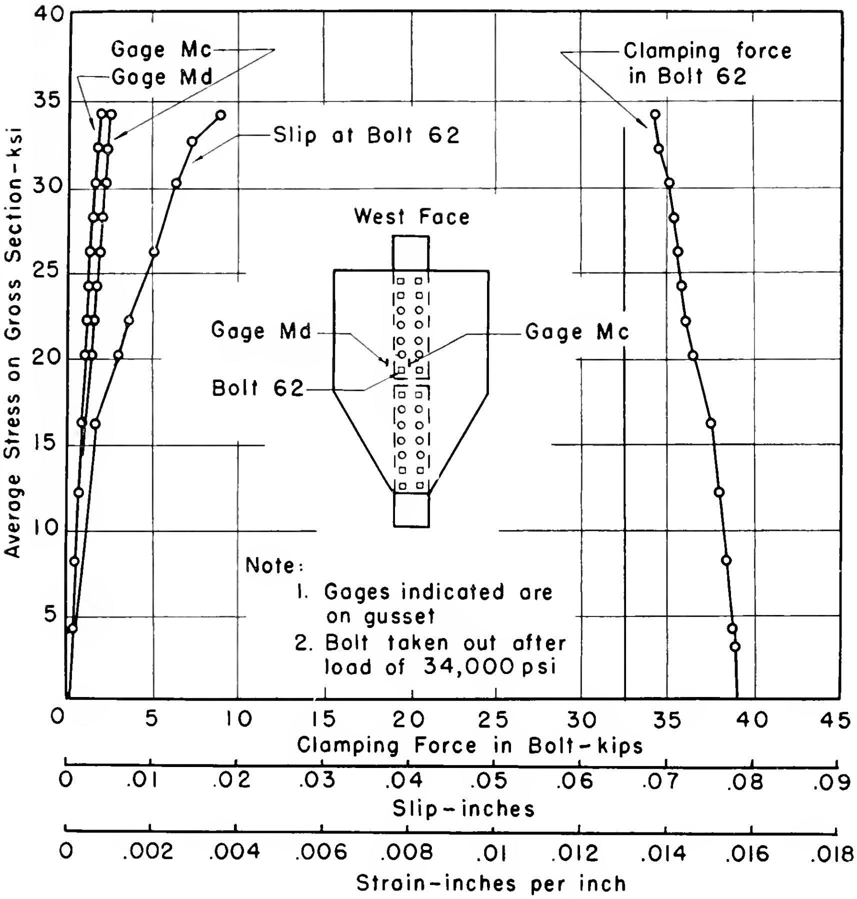


FIG. 19 CLAMPING FORCE, STRAIN AND SLIP
RIVETED AND BOLTED JOINT

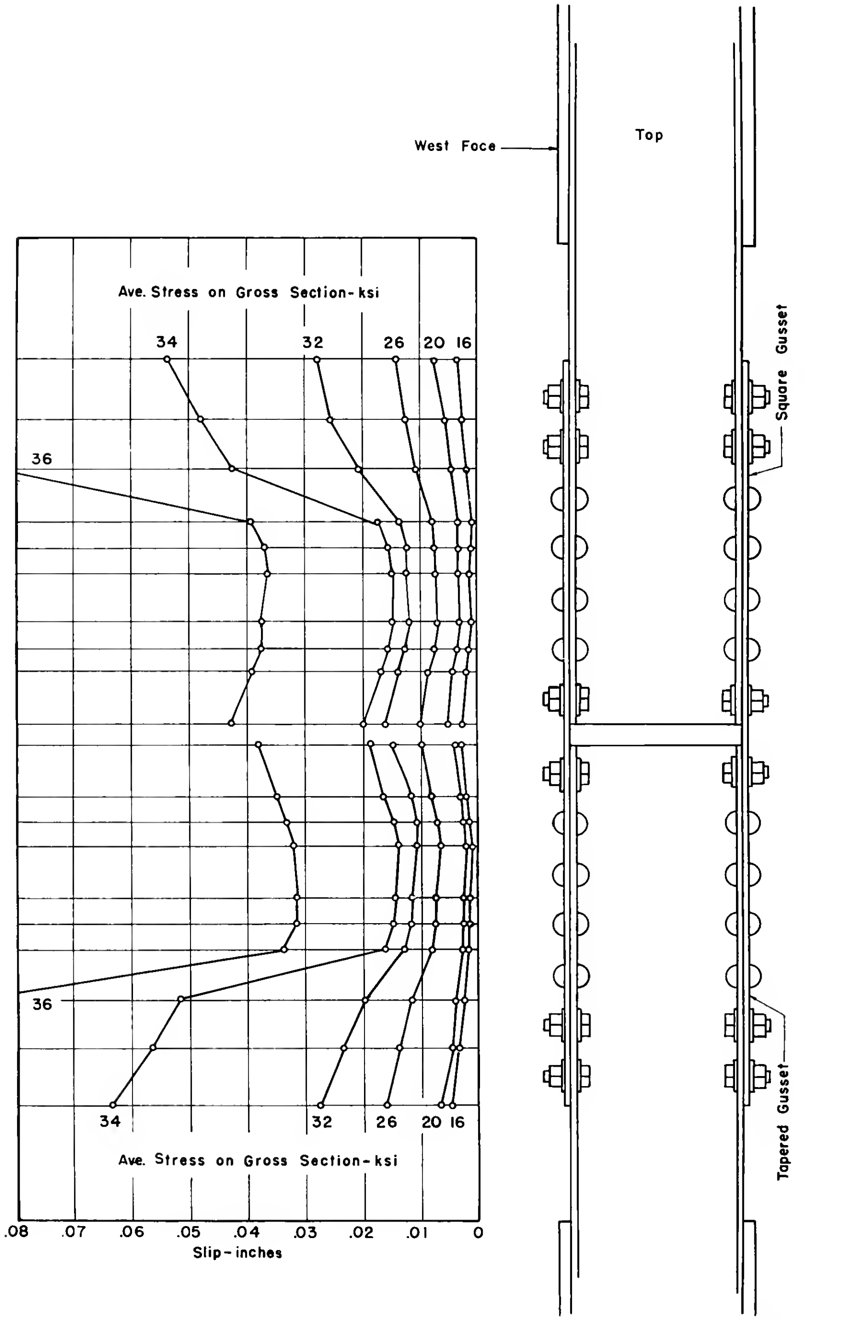


FIG. 20 SLIP DISTRIBUTION ALONG RIVETED AND BOLTED JOINT - WEST FACE

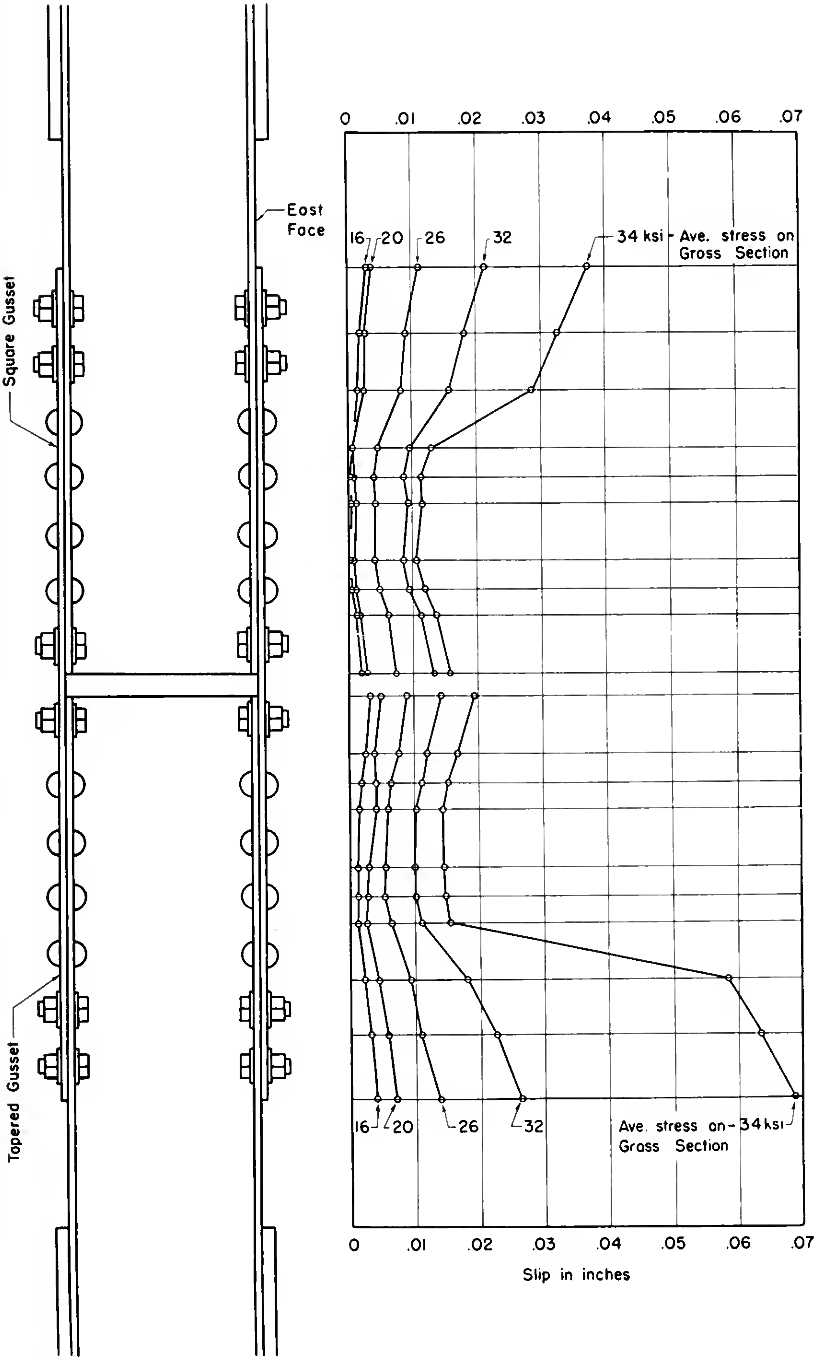


FIG. 21 SLIP DISTRIBUTION ALONG RIVETED AND BOLTED JOINT - EAST FACE

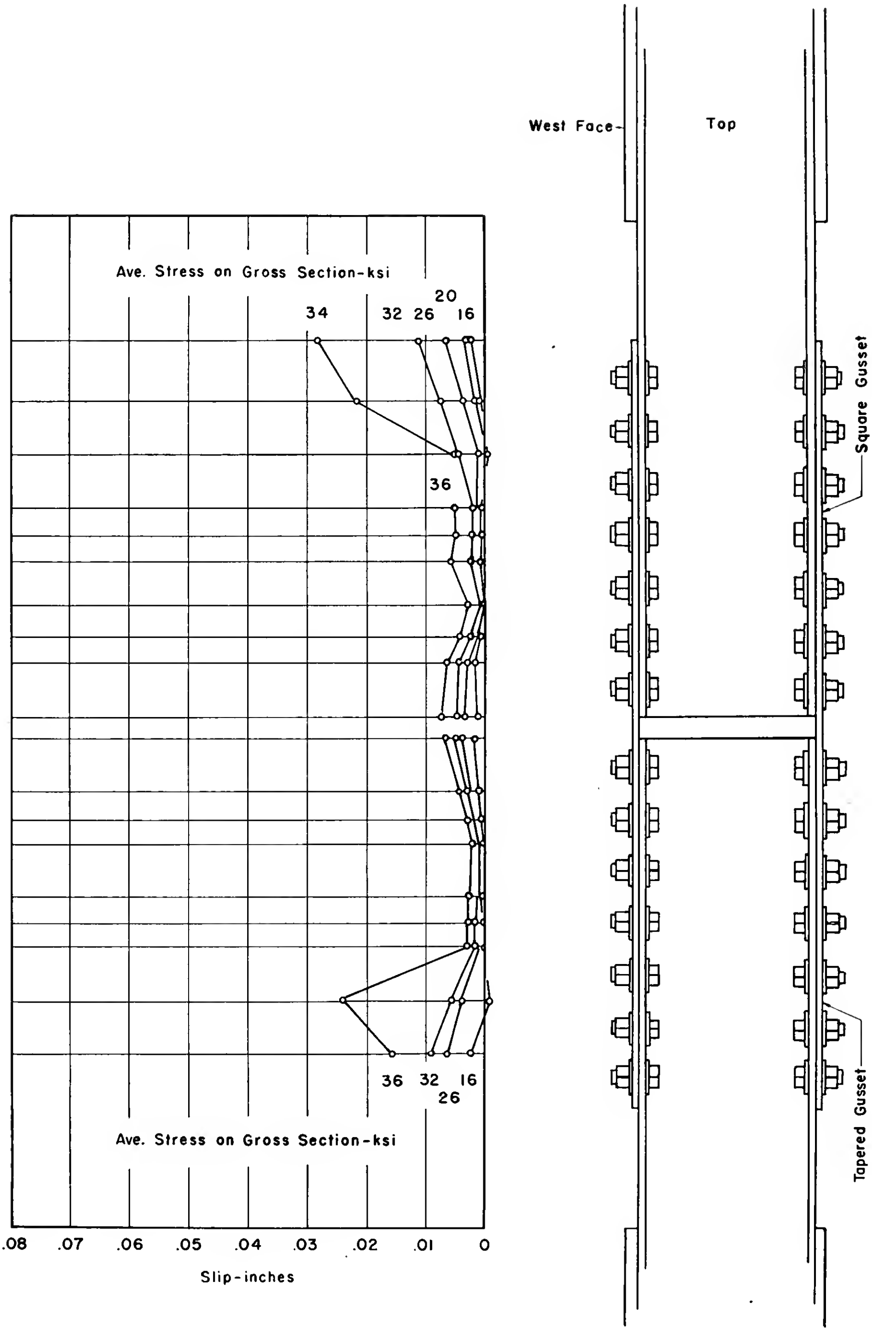


FIG. 22 SLIP DISTRIBUTION ALONG BOLTED JOINT - WEST FACE

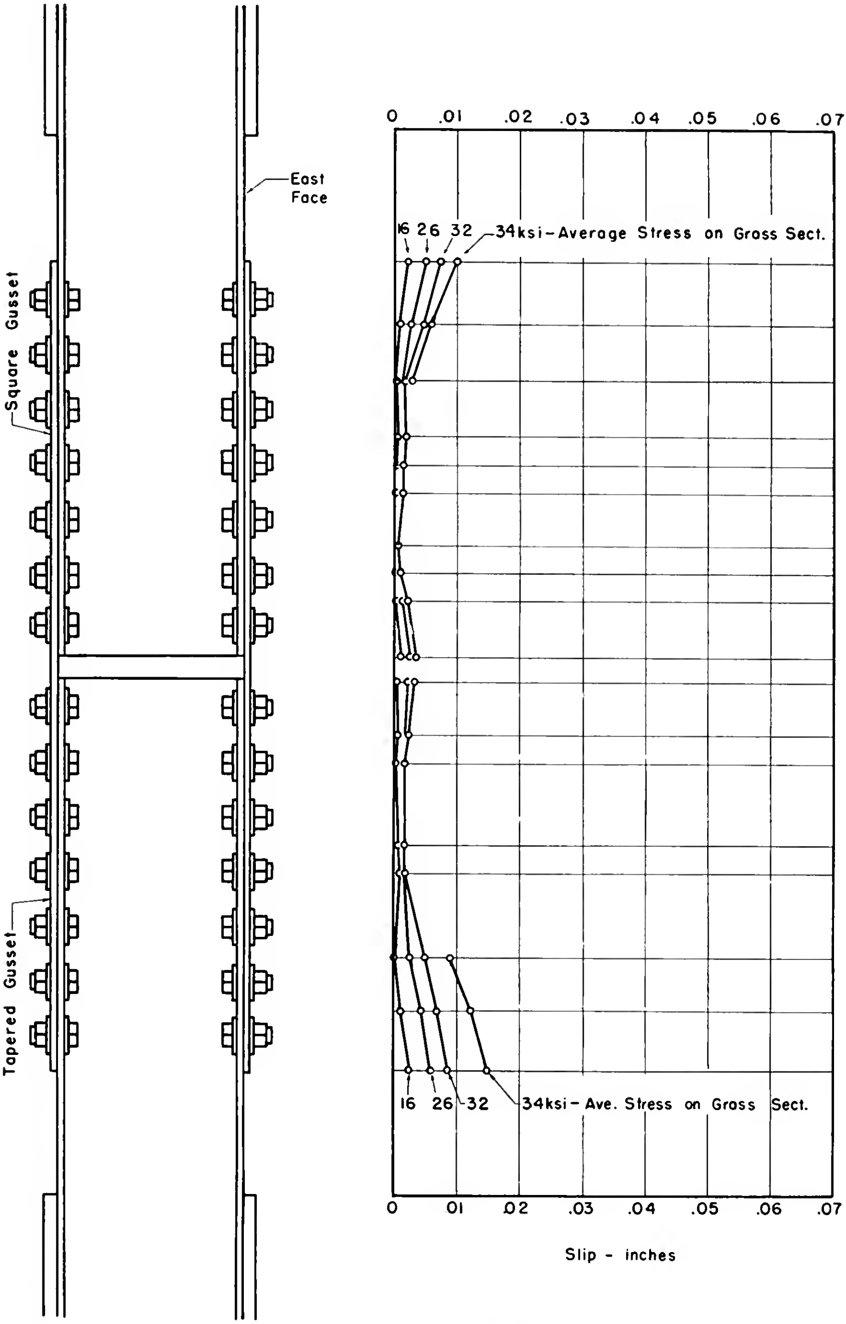


FIG. 23 SLIP DISTRIBUTION ALONG BOLTED JOINT-EAST FACE

A

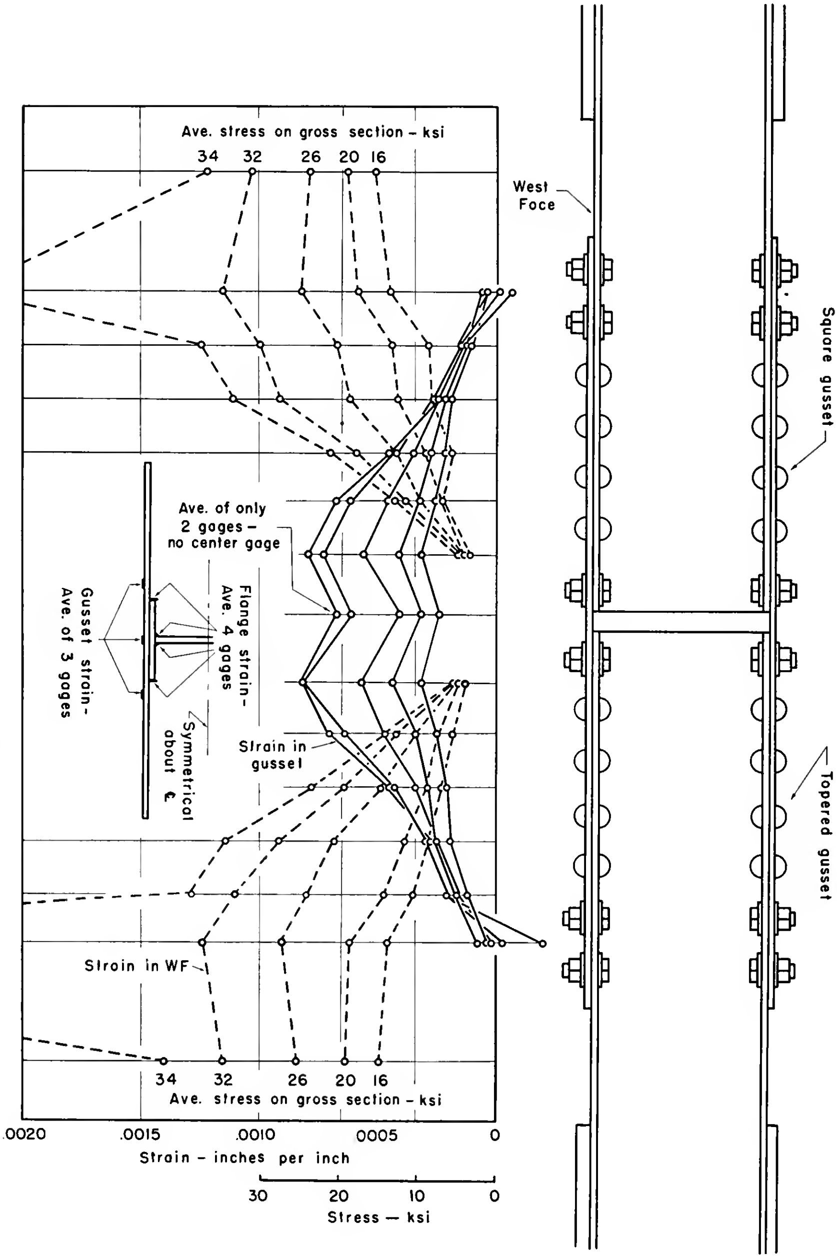


FIG. 24 STRAIN DISTRIBUTION ALONG RIVETED AND BOLTED JOINT - WEST FACE

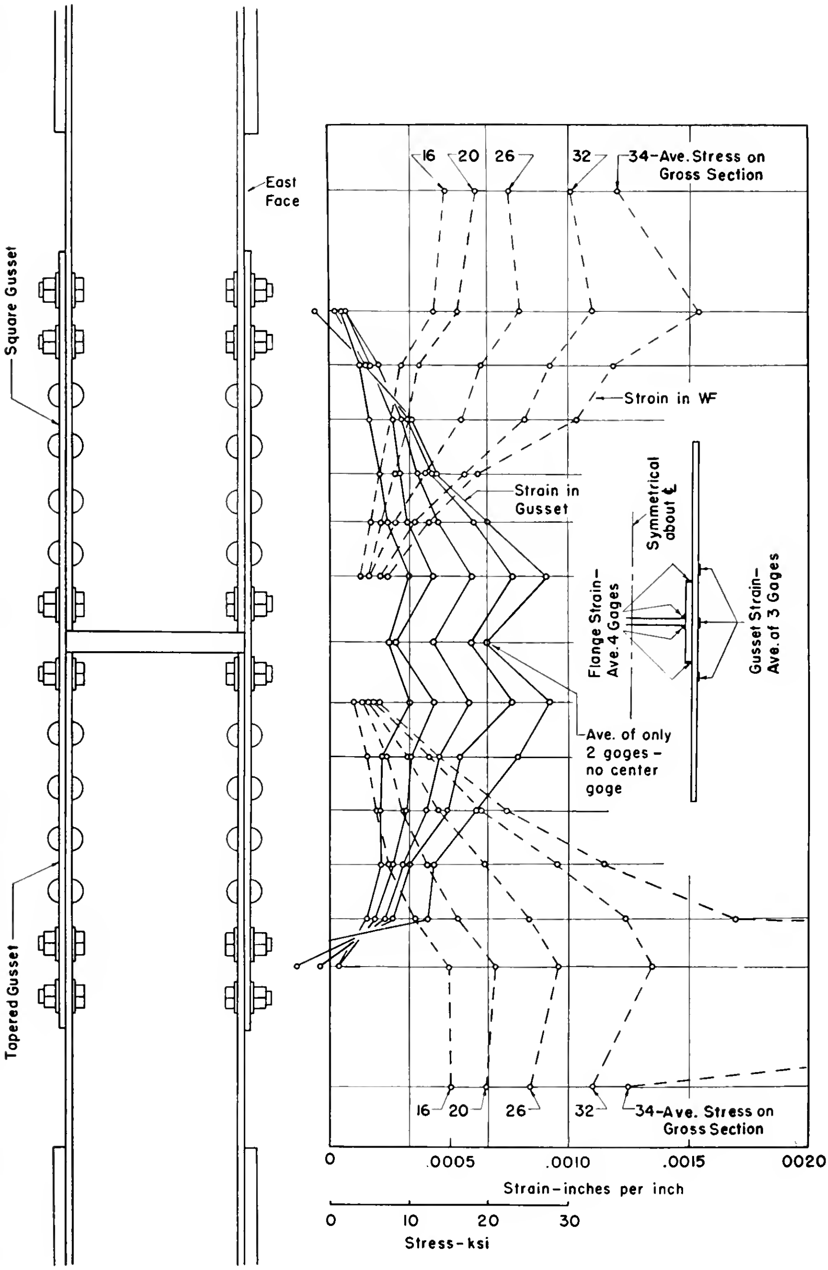


FIG. 25 STRAIN DISTRIBUTION ALONG RIVETED AND BOLTED JOINT-EAST FACE

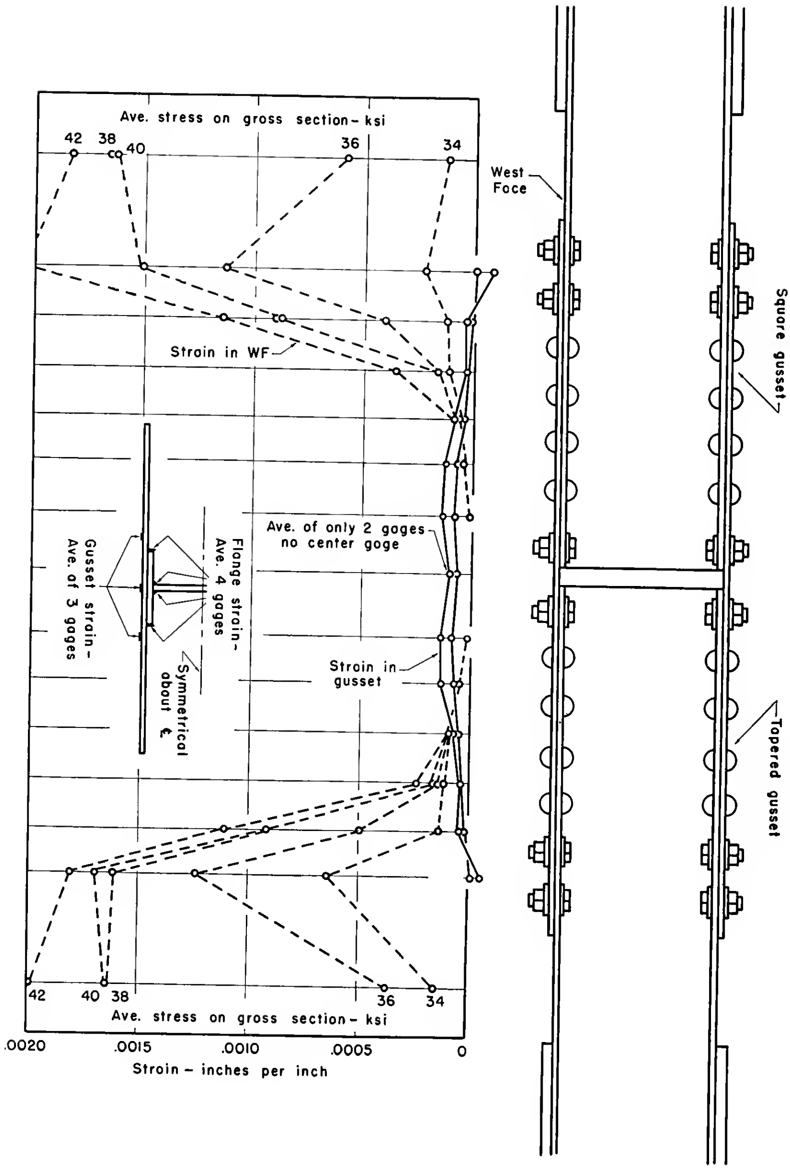


FIG. 26 STRAIN DISTRIBUTION ALONG RIVETED AND BOLTED JOINT - WEST FACE

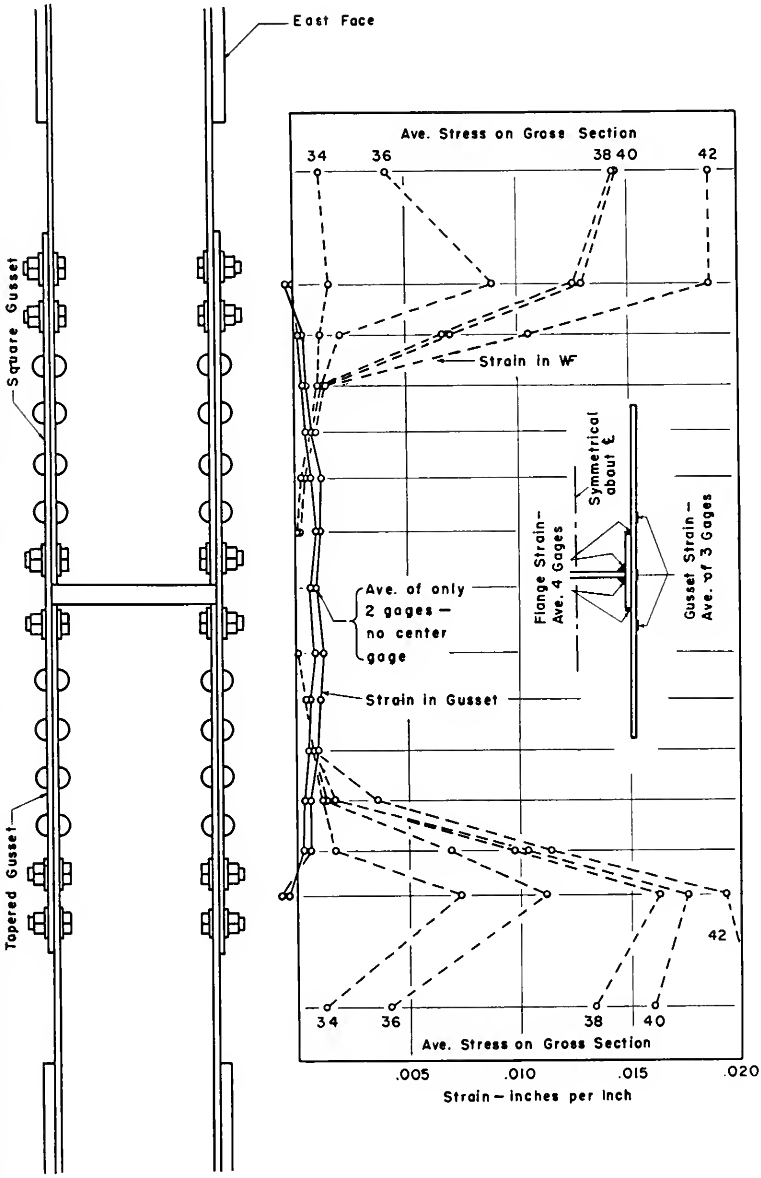


FIG. 27 STRAIN DISTRIBUTION ALONG RIVETED AND BOLTED JOINT - EAST FACE

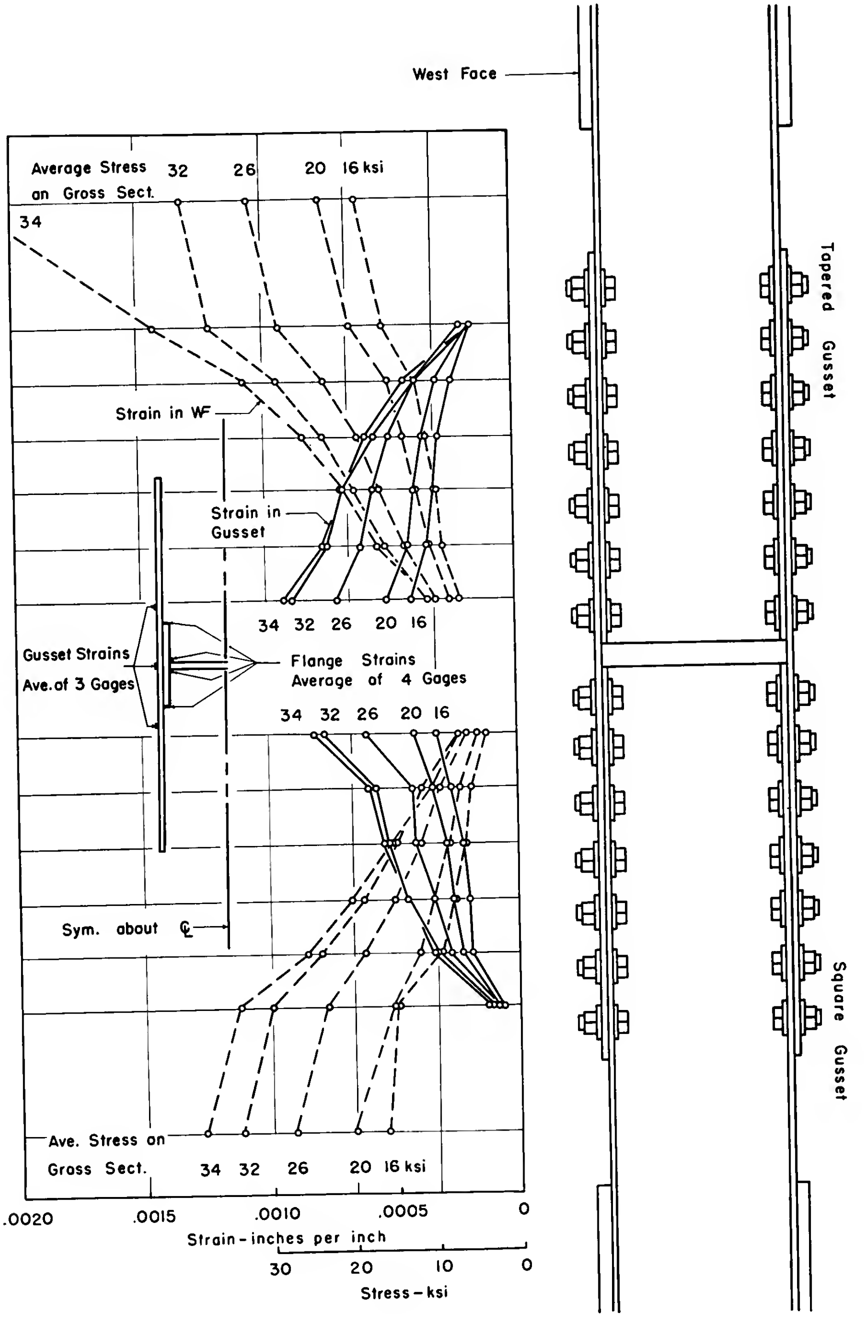


FIG. 28 STRAIN DISTRIBUTION ALONG BOLTED JOINT - WEST FACE

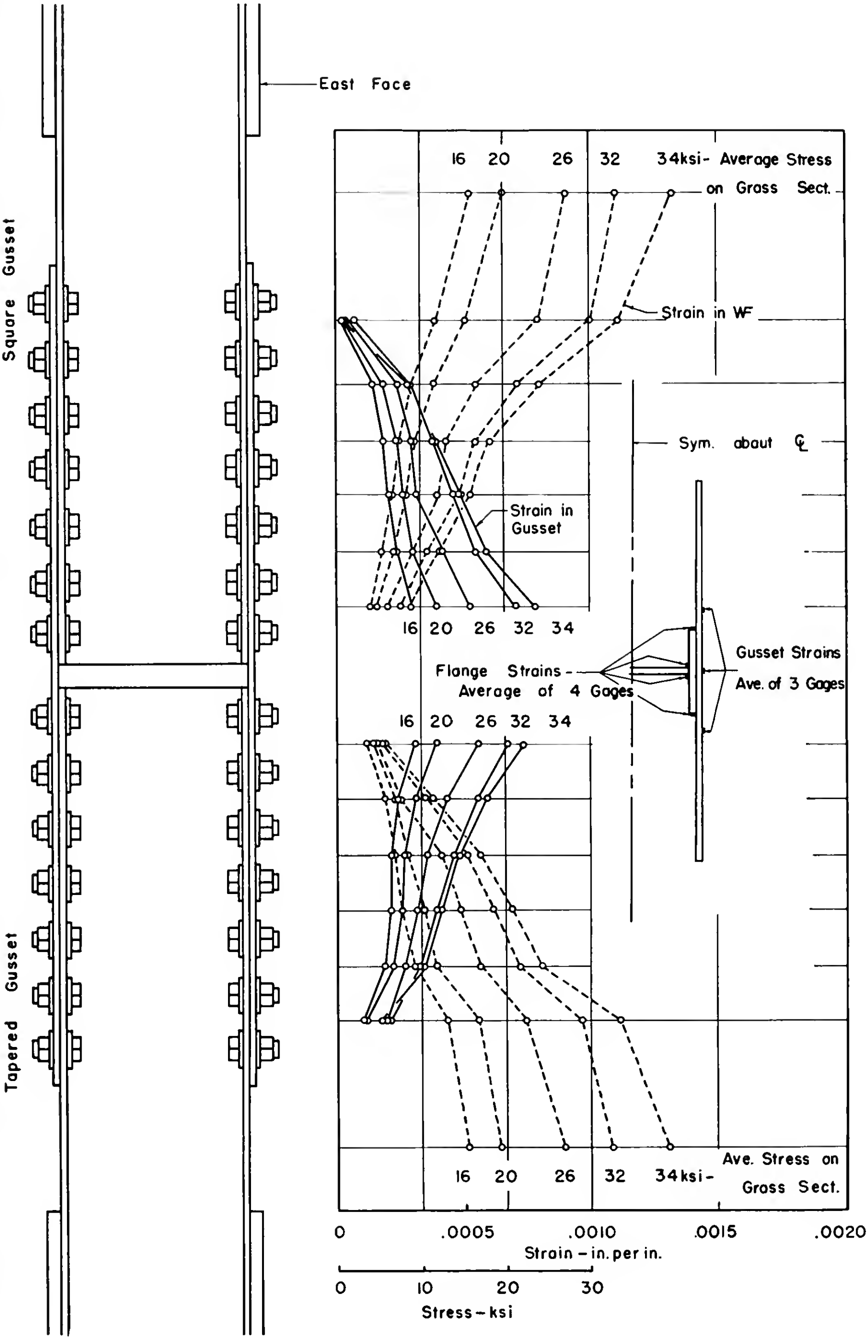


FIG. 29 STRAIN DISTRIBUTION ALONG BOLTED JOINT - EAST FACE

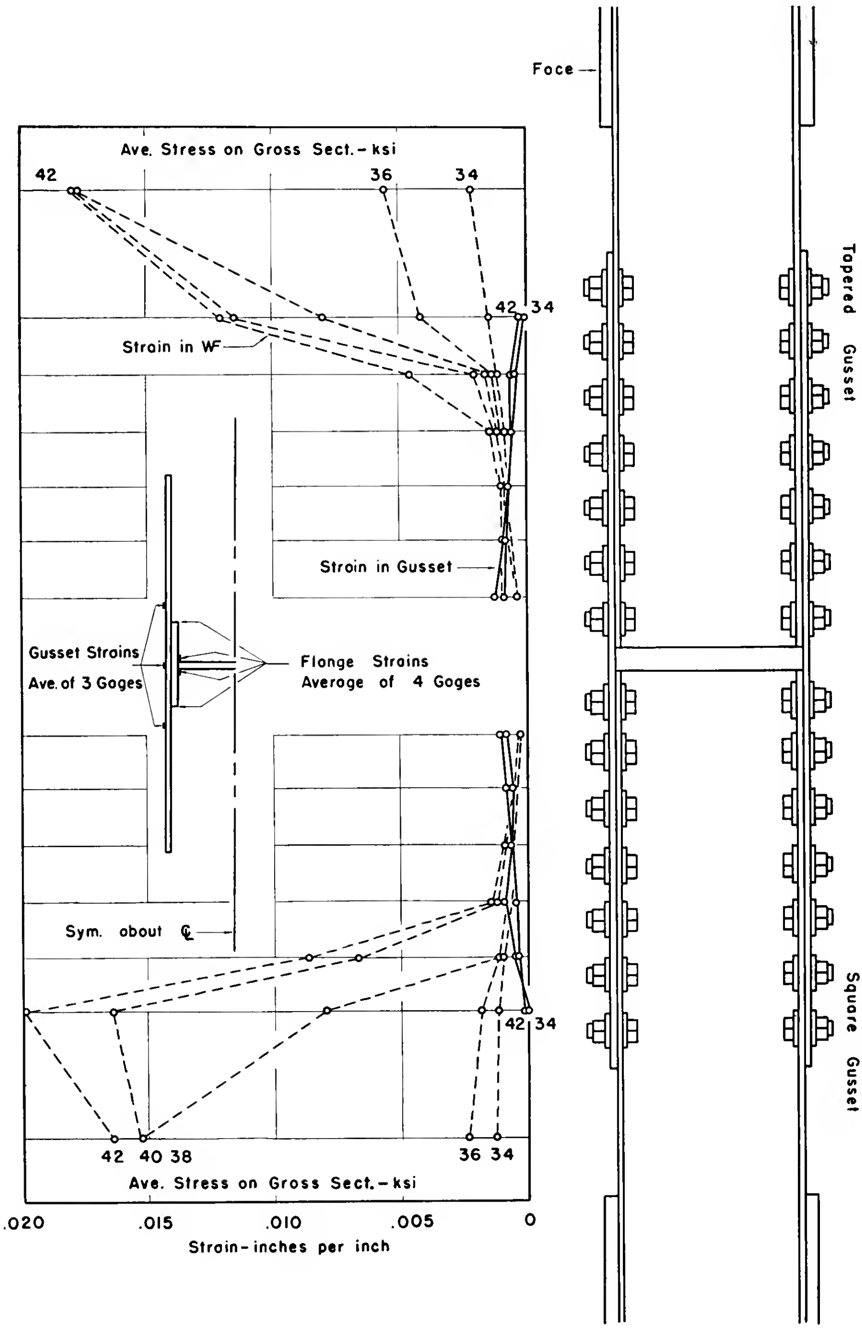


FIG.30 STRAIN DISTRIBUTION ALONG BOLTED JOINT - WEST FACE

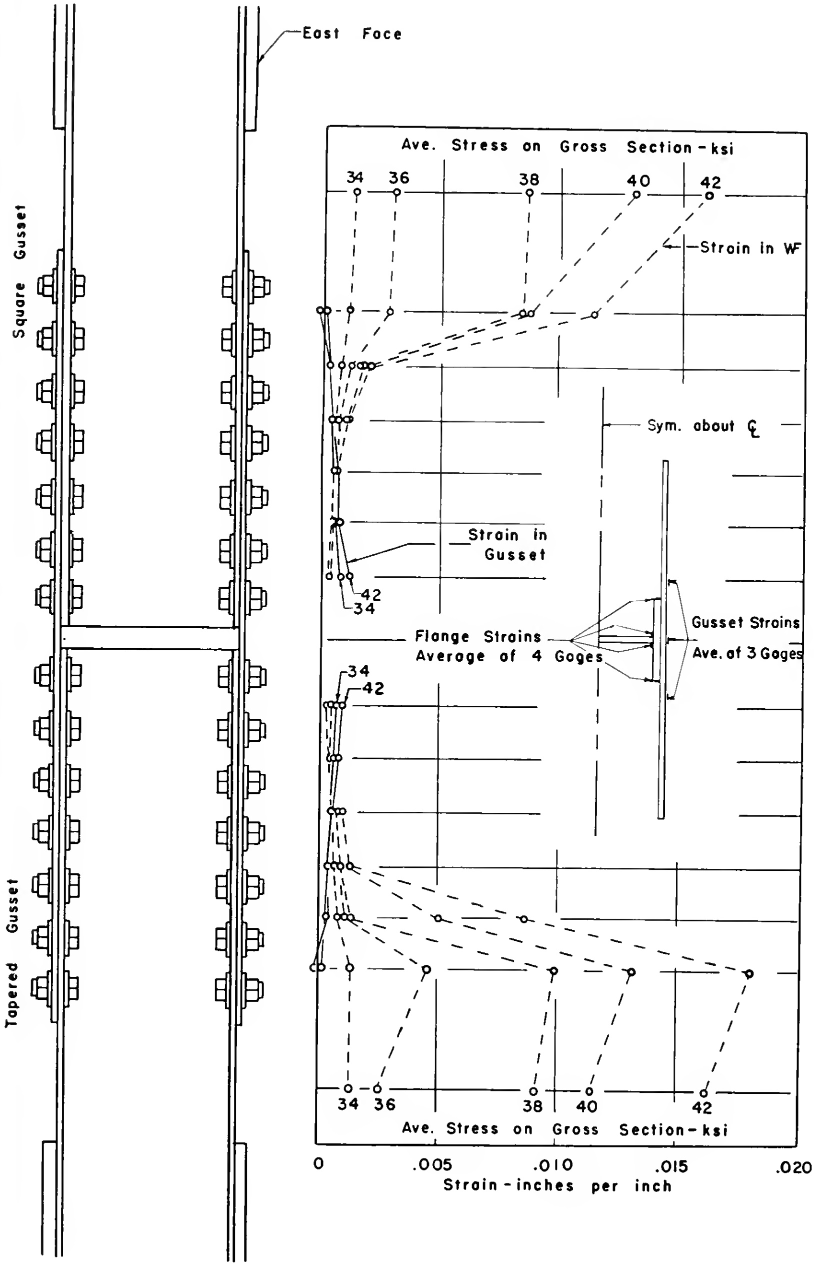


FIG. 31 STRAIN DISTRIBUTION ALONG BOLTED JOINT - EAST FACE

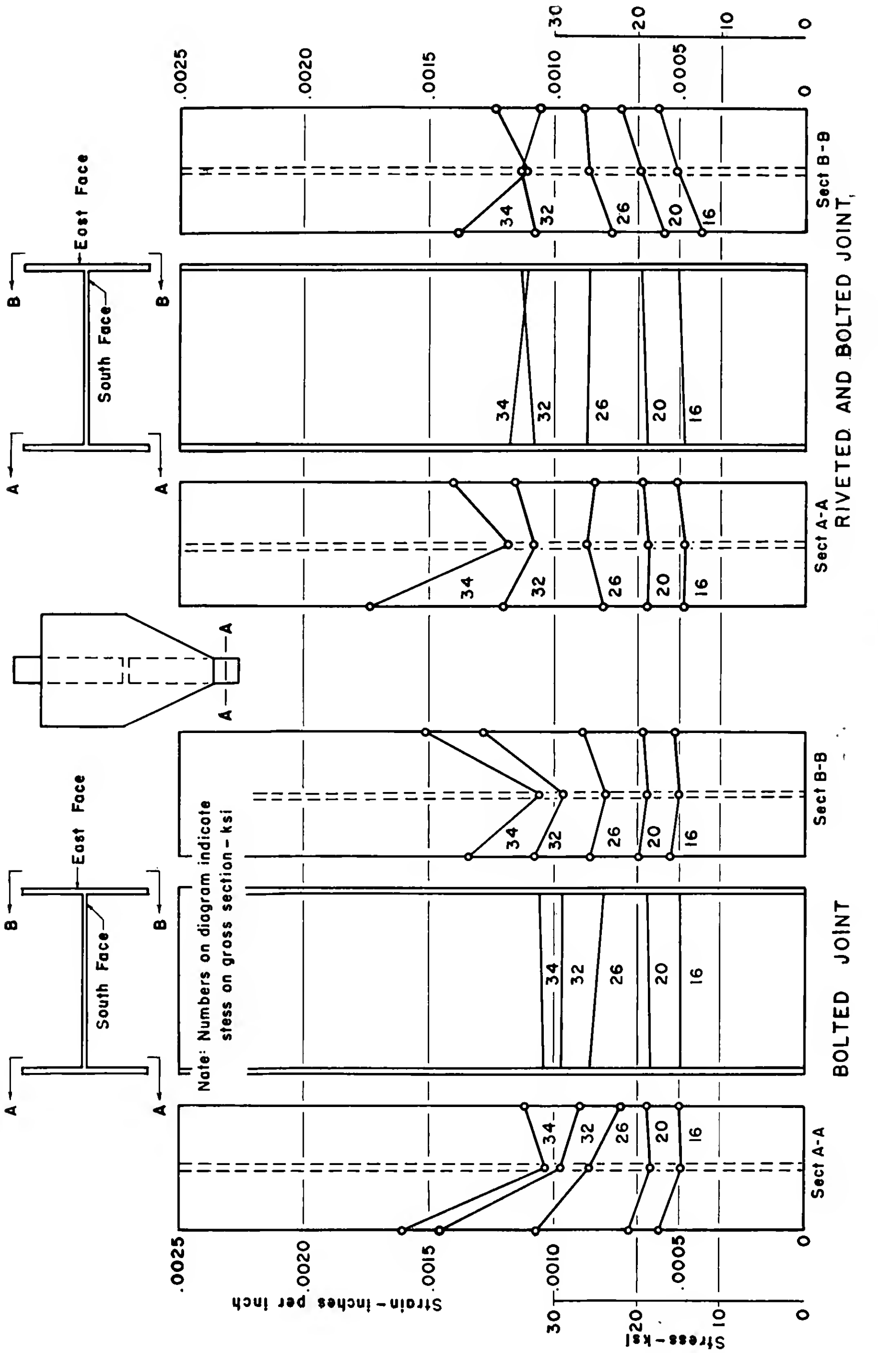


FIG. 32 STRAIN DISTRIBUTION AT SECTION A-A IN WF SECTION

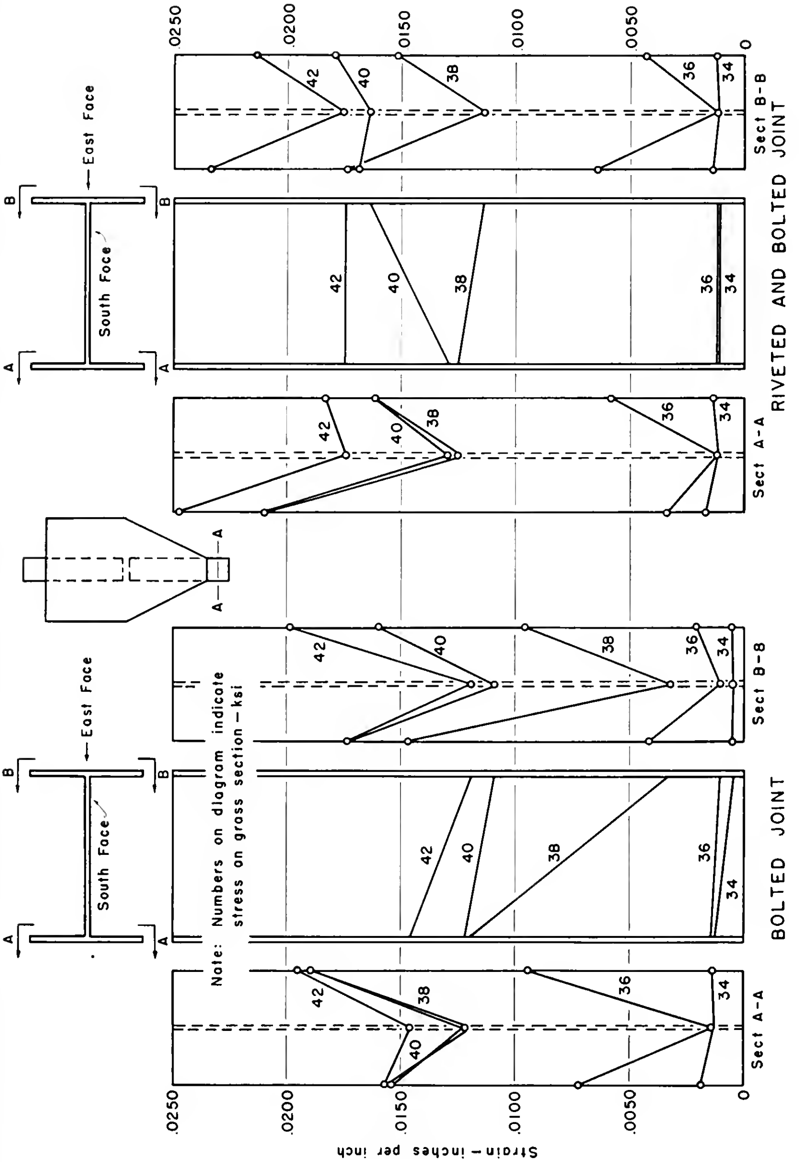


FIG. 33 STRAIN DISTRIBUTION AT SECTION A-A IN WF

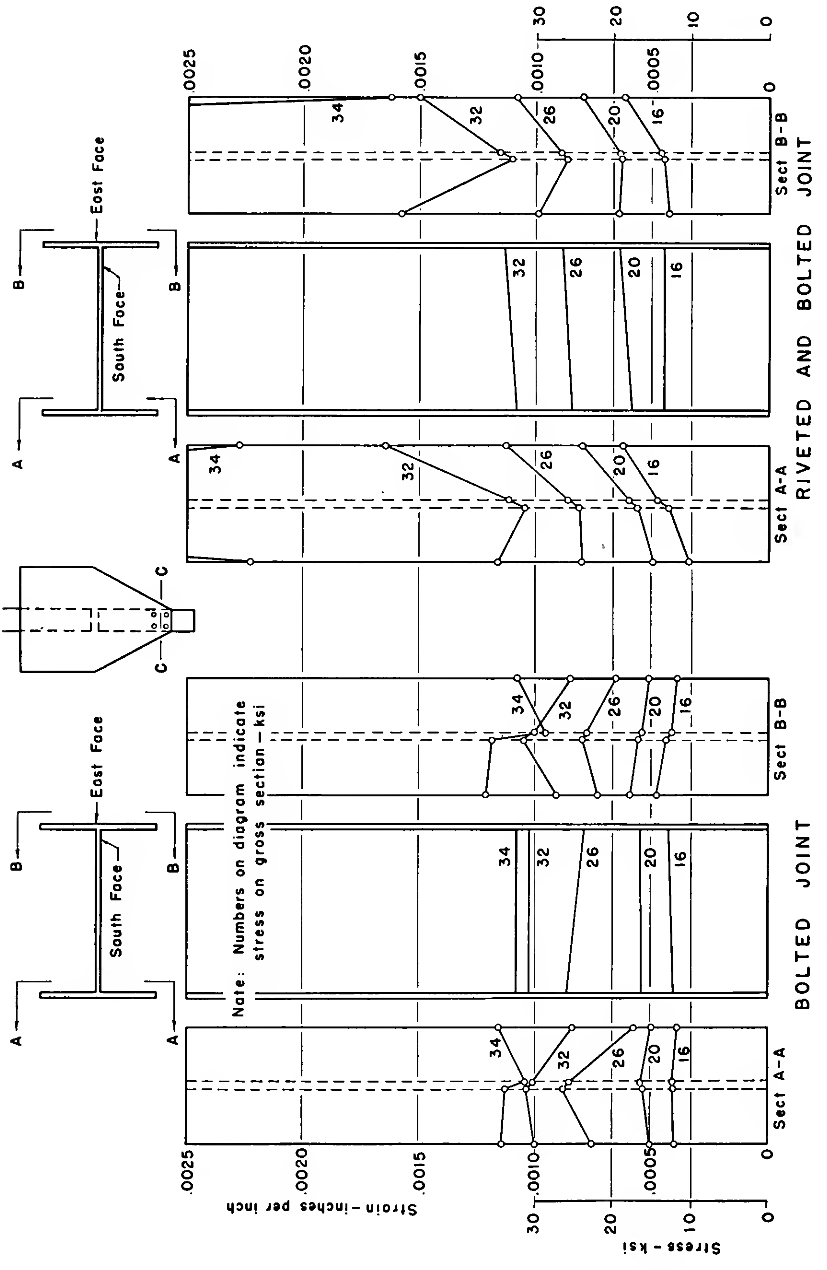
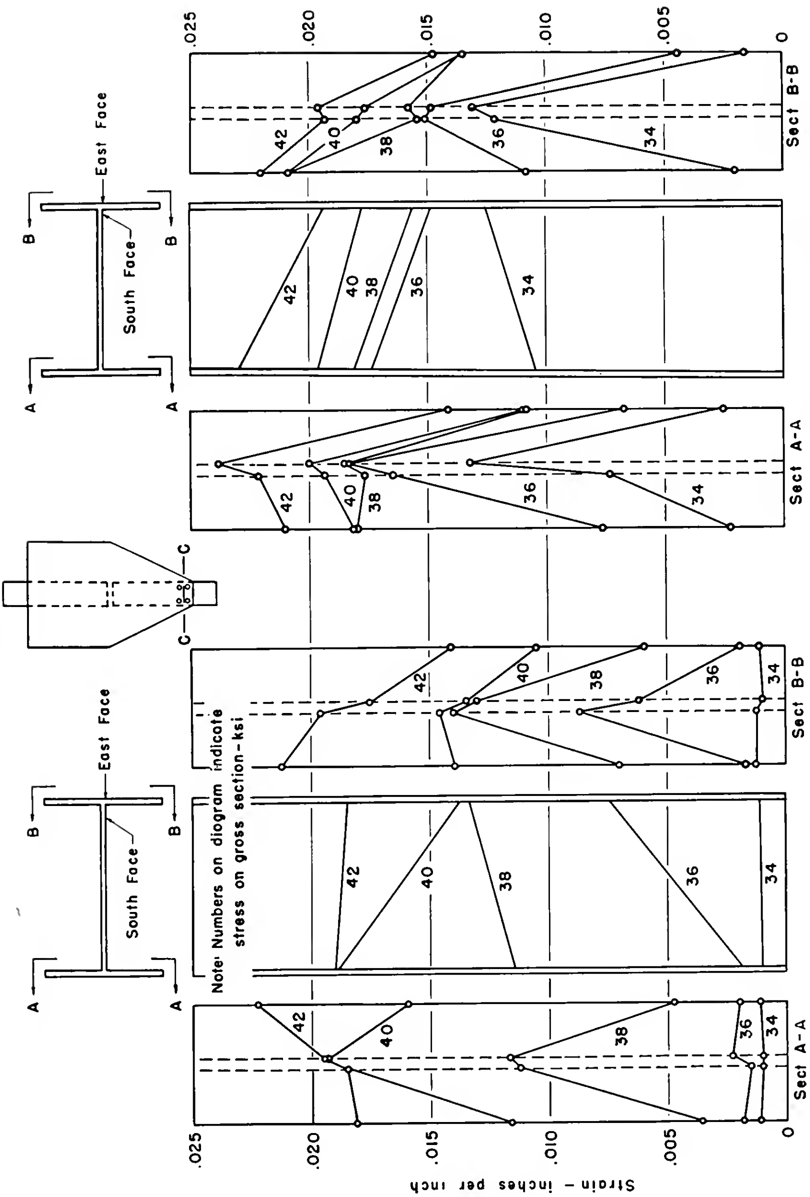


FIG. 34 STRAIN DISTRIBUTION AT SECTION C-C IN WF



BOLTED JOINT

RIVETED AND BOLTED JOINT

FIG. 35 STRAIN DISTRIBUTION AT SECTION C-C IN WF

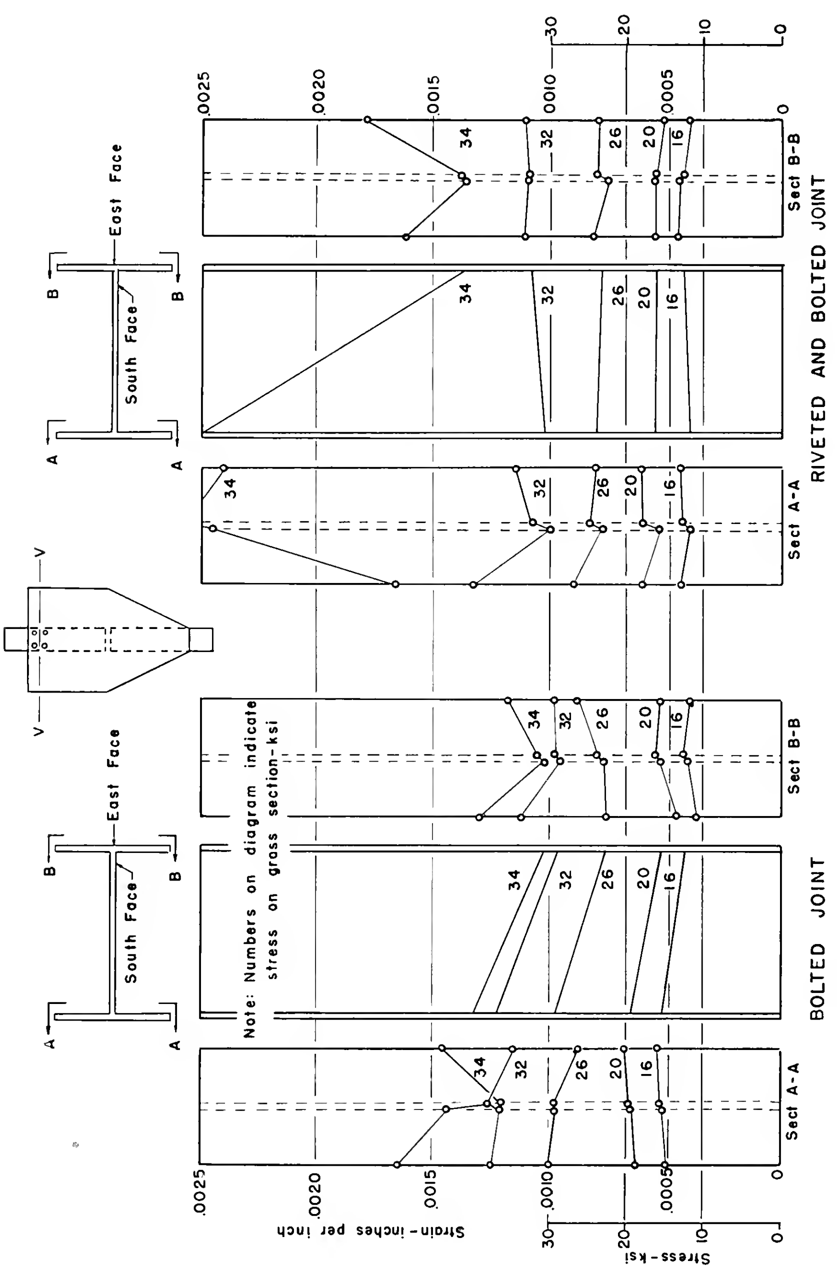


FIG. 36 STRAIN DISTRIBUTION AT SECTION V-V IN WF

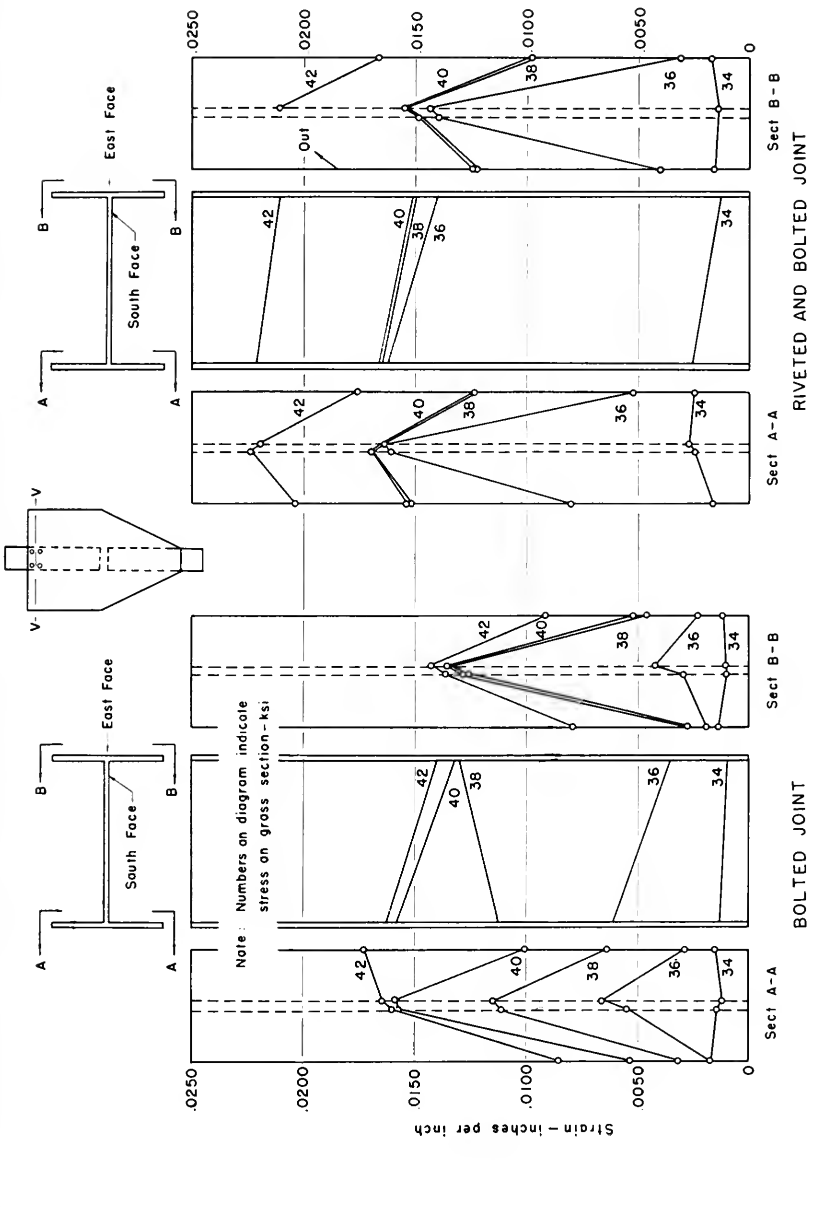


FIG. 37 STRAIN DISTRIBUTION AT SECTION V–V IN WF

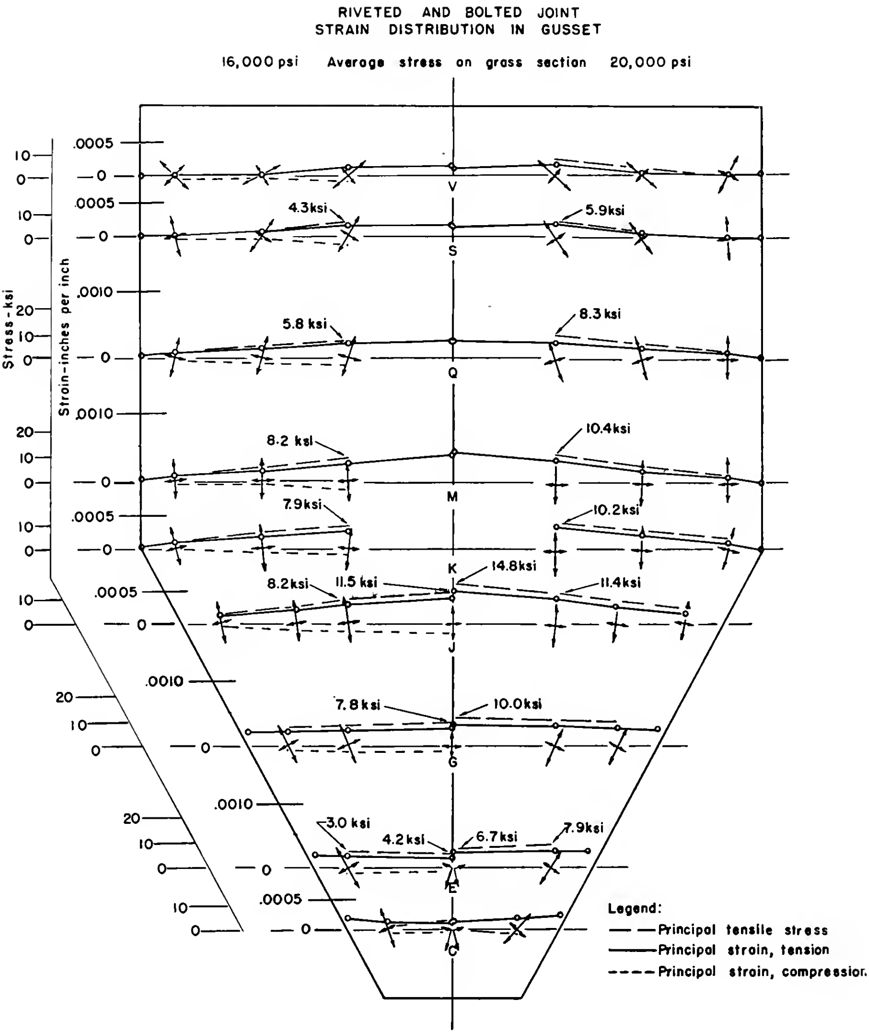


FIG. 38 STRAINS AND STRESSES IN WEST GUSSET

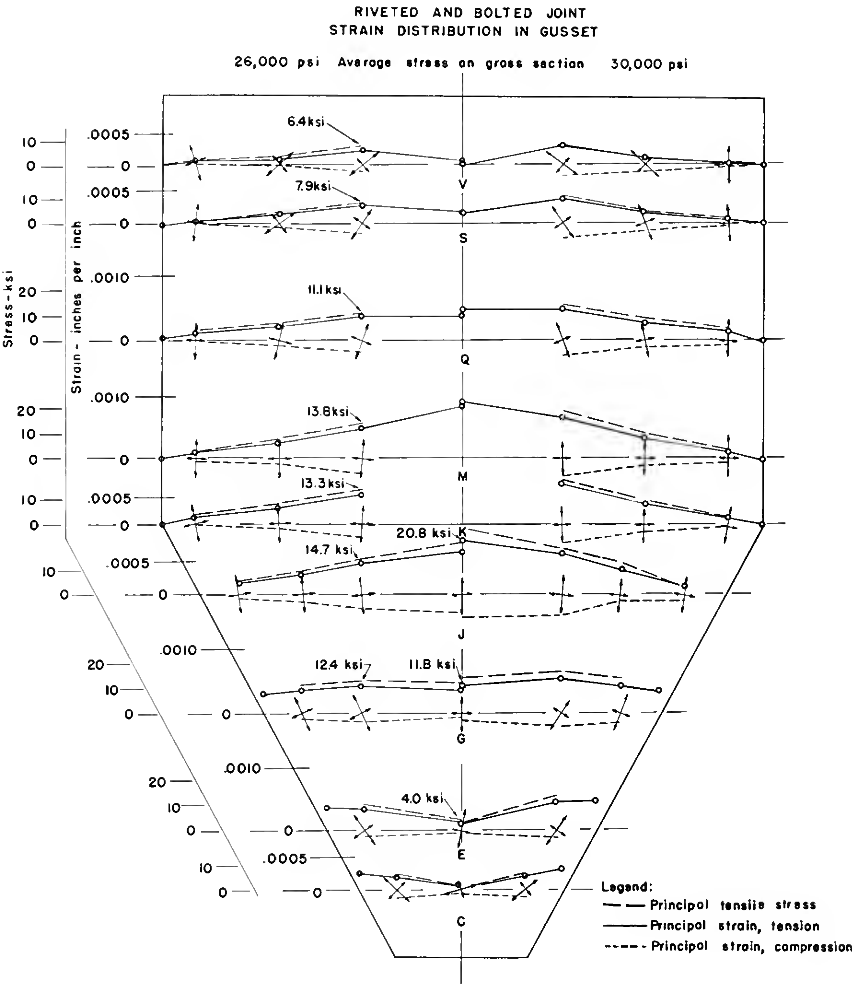


FIG. 39 STRAINS AND STRESSES IN WEST GUSSET

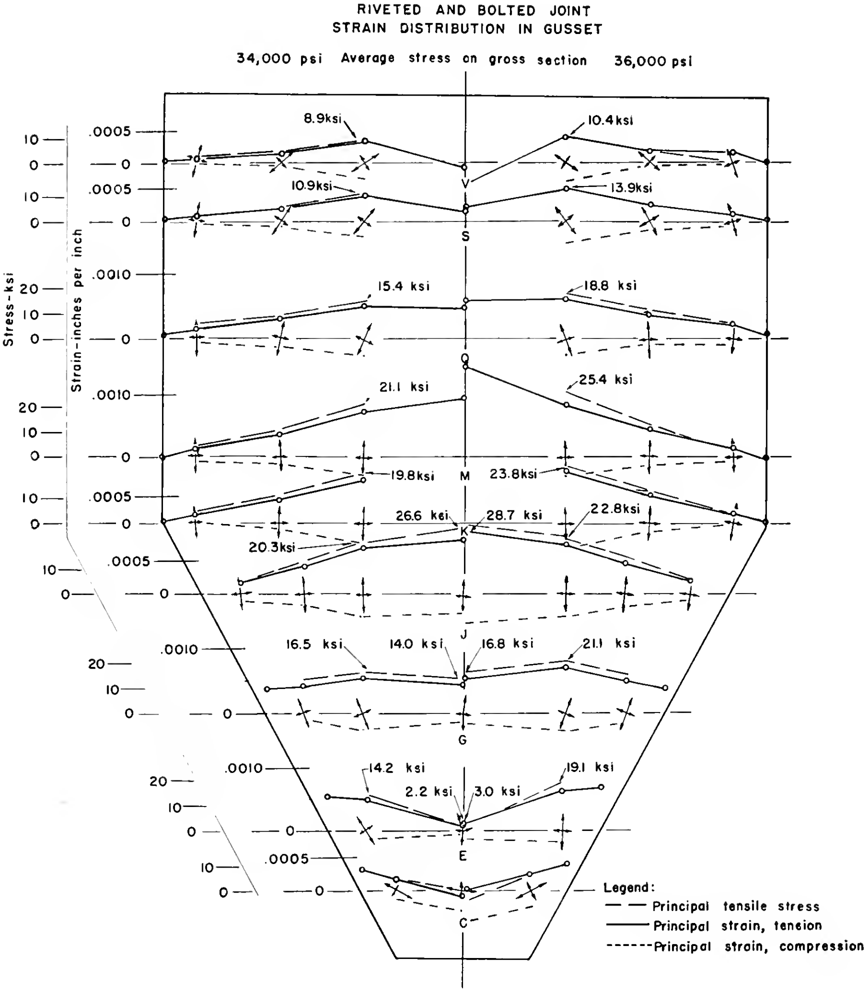
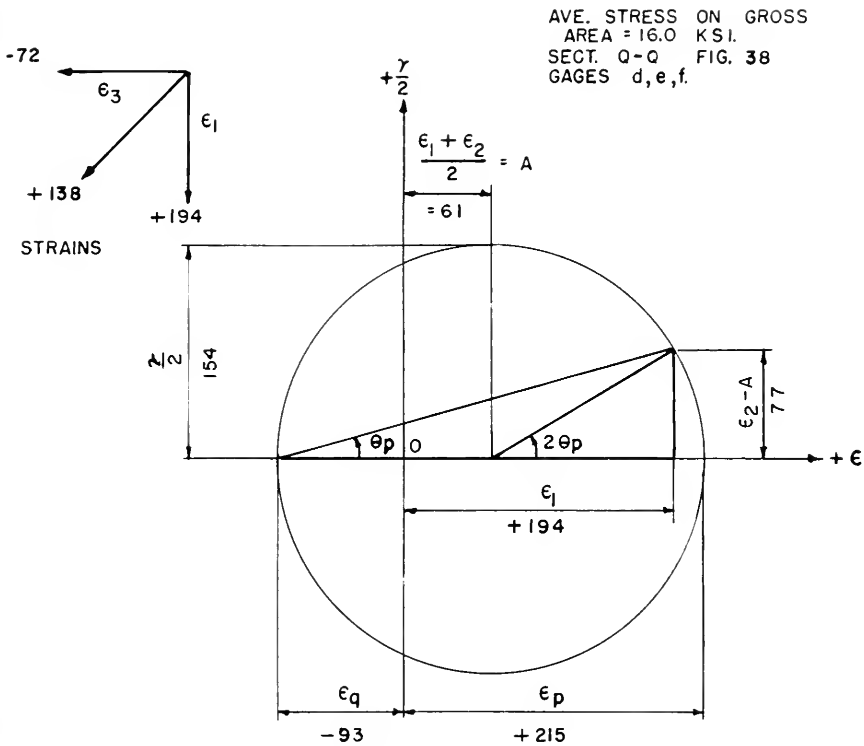


FIG.40 STRAINS AND STRESSES IN WEST GUSSET



STRAIN CIRCLE

$$p = \frac{E(\epsilon_p + m\epsilon_q)}{1-m^2} = \frac{30\,000\,000\,[215 - .3(93)]}{.91} = +6.1 \text{ KSI}$$

$$q = \frac{E(m\epsilon_p + \epsilon_q)}{1-m^2} = \frac{30\,000\,000\,[-.3(215) + 93]}{.91} = -1.0 \text{ KSI}$$

LEGEND: ϵ_p = MAXIMUM PRINCIPAL STRAIN
ϵ_q = MINIMUM PRINCIPAL STRAIN
γ = MAXIMUM SHEAR STRAIN
p = MAXIMUM PRINCIPAL STRESS
q = MINIMUM PRINCIPAL STRESS
τ MAXIMUM SHEAR STRESS

REF: PHOTOELASTICITY: M. M. FROCHT, VOL. I, P. 38, FIG. 1.35

FIG. 41 TYPICAL MOHR STRAIN CIRCLE AND PRINCIPAL STRESS COMPUTATION FOR GUSSET

Special Report of Committee 5—Track

L. L. ADAMS, *Chairman*

Curve Wear with Diesel Locomotives on the Bessemer & Lake Erie Railroad

Introduction

It has been the practice on the Bessemer & Lake Erie Railroad to handle its ore traffic between Conneaut, Ohio and the Pittsburgh District, and the returning coal traffic, with 2–10–4 type steam locomotives. Most of the traffic on the railroad ceases during the winter months when the lake is frozen. Beginning in the spring of 1952 diesel locomotives replaced about half the steam locomotives being used and in the spring of 1953 replaced the remaining steam locomotives, so that operation was completely dieselized.

It was observed during the latter part of 1952, and especially following the opening of the lake traffic in early 1953, that the high rail on curves was being severely abraded. Because of the change in type of motive power at the same time, it appeared that the introduction of diesel power was the cause of this accelerated rail wear condition. At the request of J. E. Yewell, chief engineer of the Bessemer & Lake Erie, an inspection was made of many curves on the railroad between Conneaut and Pittsburgh, especially those which had not shown abnormal wear until the introduction of diesel power. This inspection showed that the high rail of curves which were not adequately protected by rail lubricators was being very severely abraded. The gage side of the rail had tiny pits and gouges as though the metal was being torn off in small flakes (Fig. 1). The flakes of abraded metal were prominently in evidence on the top of the rail base, on the ties and on the ballast, as shown in Fig. 2. Observation of the wheels of both the diesel units and the ore cars showed this same gouging condition on the flange of the wheels. Curves protected by rail lubrication showed an entirely different condition. The gage side of the high rail on these curves showed a smooth, polished surface when the grease was wiped away, and no metal particles were in evidence on the rail base, ties or ballast. It was evident that adequate lubrication would prevent this condition of excessive rail gouging and wear.

It was further noted that the 2–10–4 steam locomotives which had been operated were equipped with flange oilers, whereas no flange oilers were being used with the diesel locomotives. There appeared to be no logical reason why the 4-wheel trucks of a diesel locomotive should produce very much more rail wear than the 4-wheel trucks of the heavy ore cars being generally used on the railroad. Apparently, the use of flange oilers on the steam locomotives was affording a substantial amount of protection against rail wear, not only from the steam locomotives but also from the entire train. With the use of diesel locomotives without flange oilers and no benefit from this lubrication, it appeared that not only the diesel but the entire train was causing rail wear.

To obtain definite information on the amount of curve wear produced by diesel locomotives relative to that produced by the remainder of the train, a series of tests was conducted in collaboration with the Bessemer & Lake Erie in May 1953. After the results of these tests were analyzed it was decided to make a second series of tests in October 1953 for the purpose of more definitely relating the effectiveness of flange oilers on the locomotive and rail lubricators in the track in controlling the amount of curve wear. These tests will be referred to as the first test series and second test series, respectively.

Instrumentation

To accomplish the purposes of the tests it was necessary to collect the amount of metal abraded by the diesel units separately from that abraded by the remainder of the train. A wooden box, approximately 30 in long, 4 in wide and 3 in deep, was devised and arranged so that it could be fastened on top of the rail base immediately under the gage side of the high rail on a curve (Fig. 3). This box was equipped with a spring trap door so that any metal abraded by the wheels of the diesel units on the head end of the train could be collected in the bottom portion of the box. The trap door could be quickly sprung between the wheels of the last diesel unit and the first ore car so that the metal abraded by the remaining wheels in the train would be caught on the top of the trap door and collected separately.

In addition to collecting the metal flakes from the rail and wheels, a motion picture camera with a floodlight was mounted just inside the high rail to photograph the position of each passing wheel flange on the high rail. Fig. 4 shows one of the test trains approaching for a test run, the camera and the collecting box being evident toward the left lower portion of the photograph.

First Test Series

Tests were made under two full-tonnage trains on a 7-deg 30-min curve near Conneaut, Ohio, on May 26, 1953, and under three full-tonnage trains on May 27. Trains were operated on a turn-around movement between Conneaut and Albion, Ohio, a distance of about 14 miles. Three trains, each consisting of approximately 110 cars and 13,500 gross tons, were sufficient to transport the contents of 1 ore boat between these 2 points. Three turn-around movements were operated in one 8-hr trick, and the same 5 diesel units were in use on each train under which the tests were made. For each train 3 diesel units were on the head end and 2 diesel units were on the rear end as pushers. The test location was on a 1 percent ascending grade and the speed was about 15 mph.

The steel flakes and particles ground from the rail and wheels and caught in the box were removed from the box by means of a small magnet and placed in separate envelopes, the quantity obtained from the 3 head-end diesel units being placed in 1 envelope and that from the 110 ore cars and the 2 diesel pusher units in another envelope.

A surprisingly large quantity of metal flakes was collected in the box for each of the two test runs for the first day, May 26. On the following day a strong wind was blowing, which appeared to carry most of the metal particles across the rail and a much smaller quantity was collected. The metal particles as collected separately for the three diesel units and for the remaining cars and two pusher units are shown in the test tubes in Fig. 5. It will be readily noted from this photograph that a large amount of metal was ground from the wheels and rail on runs 1 and 2, and that by far the major portion of this metal came from the cars and the two pusher diesel units rather than from the three head-end diesel units. In Table A the weight of the metal abraded from the rail and wheels and collected during one train passage is shown for each run. Col. 2 shows the weight collected for the three head-end diesel units. Col. 3 shows the average collected per diesel unit. In Col. 4 the weight of the metal removed by the remainder of the train, excluding the two pusher diesel units, has been obtaind by subtracting from the total the estimated amount for the two pushing units based upon the quantity per diesel unit shown in Col. 3. In Col. 5 the average amount of metal removed per ore car is thus obtained. Comparing Cols. 5 and 3 it will be observed that for runs 1 and 2, where most of the metal abraded was apparently collected in the box, the amount of metal abraded per diesel unit was from four to five times the amount abraded per ore car.

There may justifiably be some question as to whether the metal might be ground loose by the three head-end diesel units and removed from the rail by the ore car wheels. However, the abraded metal particles looked like snow flakes in the glare of the floodlight and it was apparent during the train passage that metal particles were being ground continuously by wheels throughout the entire train length. Occasional wheels ground a larger shower of flakes than others, and it is presumed that they were wheels with sharper flanges.

Second Test Series

The purpose of the second test series as previously stated was to evaluate the effectiveness of flange oilers on the diesel units and of rail lubricators in the track in controlling the amount of wheel and rail wear on curved track. The second test series was run from October 13 to October 23, 1953, incl. A change was made in the operation procedure for the second test series. Four diesel units were equipped with Prime Forced Feed oil-type flange lubricators (Fig. 6). The tests were run with the four diesel units on the head end of the train and the tonnage adjusted accordingly, rather than use three head-end units and two pusher units as in the first series. Rail lubrication was provided by a Meco graphite grease-type rail lubricator (Fig. 7). The second series of tests was run with four different conditions as follows:

1. Flange oilers on the locomotives working, rail lubricator out of service, and the rails cleaned off before the test.
2. Flange oilers on the locomotive and rail lubricator on the track both in service and operating.
3. No lubrication from either locomotive flange oilers or rail lubricator, the rail being cleaned off prior to the test.
4. Rail lubricator working with the flange oilers on the locomotive out of service.

Generally, five test runs were made for each condition. The results obtained are shown in Table B. For condition 1, with flange oilers only, it will be noted that for the first run after the rails were cleaned there was a considerable amount of metal abraded. This declined on the next two runs as successive passages of the trains built up an oil film. Between runs 3B and 4B, due to a misunderstanding, two trains were operated over the test curve without flange oilers, and as a result, the metal abraded was again large on run 4B. Accordingly, after the runs for condition 2 were completed the rail was again cleaned, with kerosene, from the track lubricator approximately 1 mile away to the test location, and runs 10B and 11B were made with the flange oilers on the locomotive only in operation. It will be observed that for both of these runs the amount of metal abraded was quite nominal. It is evident from these results that the use of flange oilers on all trains operated around the curve would be quite effective in providing rail lubrication as well as wheel lubrication, and in reducing the amount of metal abrasion of wheel and rail to a very considerable extent.

For the five test runs in condition 2, having both rail lubricators and flange oilers, it is evident that the rail and wheels were quite effectively protected, and that the amount of metal abraded was practically nil.

For the five test runs shown in condition 3, with no lubrication, the rail was again cleaned with kerosene and waste between the track lubricator and the test location. However, it is evident that for the first run with this condition there was sufficient lubricant remaining on the rail to offer fair protection. On succeeding runs the amount of cutting increased until for the last two runs, 15B and 16B, it was a very substantial amount.

For test condition 4, having rail lubricators only, it is quite apparent that the rail and wheels were being effectively protected, and the amount of metal abraded was again practically nil.

It is evident from the results obtained in the second test series that the use of rail lubricators can provide practically complete protection against abrasion of rail and wheels on the high rail of curves and that the use of flange oilers on all power units would also provide very effective protection, although not to quite the same extent as rail lubricators.

Tracking Characteristics

The motion pictures taken of the wheel position relative to the high rail showed very interesting tracking characteristics of the diesel unit trucks as compared with the ore car trucks. Fig. 8 shows the wheel flange position of the three head-end diesel units on the high rail (first test series), and it will be observed that in each case the wheel of the leading axle of each truck was crowding the high rail. However, the wheel of the trailing axle was quite some distance from the high rail, perhaps as much as ¾ to 1 in. Fig. 9 shows the corresponding wheel flange positions for the first three ore cars in run 1. It will be observed that also for the ore cars the wheel of the leading axle of each truck is crowding the high rail and the wheel of the trailing axle is only slightly away from the high rail—⅛ to ¼ in.

It has generally been considered that the guiding characteristics of a 4-wheel truck are such that the trailing axle assumes a radial position on the curve and the leading axle crowds the outer rail. This was observed even as far back as Wellington's time because he explains this characteristic in his book on The Economic Theory of Railway Location, Sixth Edition, page 284. Fig. 10 illustrates this guiding characteristic, and it will be noted from this figure that the distance of the wheel on the trailing axle of a 4-wheel truck from the outer rail may be very simply calculated as the mid-ordinate to the curve of a chord equal in length to twice the truck axle spacing. Calculations made for the ore car trucks having an axle spacing of 5 ft 6 in and the diesel trucks having an axle spacing of 9 ft, indicate that these mid-ordinates are 0.24 in and 0.64 in, respectively. It appears that these calculated mid-ordinates agree reasonably well with the positions assumed by the wheels of both the diesel units and ore cars against the high rail. This would indicate, therefore, that there is no effect of the tractive power on the diesel trucks to cause excessive pressure of the leading wheel against the high rail. The greater angulation of the wheel flange against the high rail because of the longer wheel base of the diesel units might very well explain the increased rate of rail and wheel wear of the diesel units relative to that of the ore cars.

Conclusions

It may be concluded from these tests that although the rate of rail and wheel wear with a diesel unit is somewhat greater than for a heavily loaded freight car, nevertheless, by far the greater amount of rail wear is due to the train rather than the diesel units. The tests further showed that rail and wheel flange wear on curved track can be practically eliminated by lubrication with either flange oilers on the diesel units or rail lubricators in track, or a combination of the two.

Acknowledgement

These tests were conducted and this report was prepared in collaboration with the Bessemer & Lake Erie Railroad by the AAR Engineering Division research staff under the general direction of G. M. Magee, director of engineering research. The actual draft of the report was written by Randon Ferguson, electrical engineer, and A. L. Flassig, Jr., test assistant. J. E. Yewell, chief engineer, J. W. Hopkins, engineer of track, and S. O. Rentschler, superintendent of motive power, all of the B&LE, provided the necessary facilities and assistance for conducting the tests.

TABLE A

First Test Series

Material Abraded from Rail and Wheel and Collected During One Train Passage

(Weight in Grams)

Run	Three Diesel Units	Per Diesel Unit	Total Ore Cars	Per Ore Car
(1)	(2)	(3)	(4)	(5)
#1	0.50	0.17	3.49	.032
#2	0.49	0.16	4.58	.043
#3	0.23	0.08	0.29	.003
#4	0.15	0.05	0.19	.002
#5	0.20	0.07	1.02	.009

TABLE B

Second Test Series

Material Abraded from Rail and Wheel and Collected During One Train Passage

Run	Four Diesel Units	Per Diesel Unit	Total Ore Cars	Per Ore Car
Condition 1. - Flange Oilers Only				
1B	0.124	0.031	0.468	0.005
2B	0.081	0.020	0.136	0.001
3B	0.024	0.006	0.079	0.001
4B	0.081	0.020	1.124	0.013
10B	0.000	0.000	0.000	0.000
11B	0.007	0.002	0.060	0.001
Condition 2. - Both flange oilers and rail lubricators.				
5B	0.030	0.007	0.027	0.000
6B	0.000	0.000	0.001	0.000
7B	0.000	0.000	0.000	0.000
8B	0.000	0.000	0.000	0.000
9B	0.000	0.000	0.000	0.000
Condition 3. - No Lubrication				
12B	0.061	0.015	0.022	0.000
13B	0.060	0.015	0.120	0.001
14B	0.022	0.006	0.436	0.005
15B	0.139	0.035	2.428	0.027
16B	0.077	0.019	1.333	0.014
Condition 4. - Rail Lubricators only				
17B	0.010	0.003	0.018	0.000
18B	0.004	0.001	0.012	0.000
19B	0.000	0.000	0.000	0.000
20B	0.007	0.002	0.021	0.000
21B	0.000	0.000	0.000	0.000

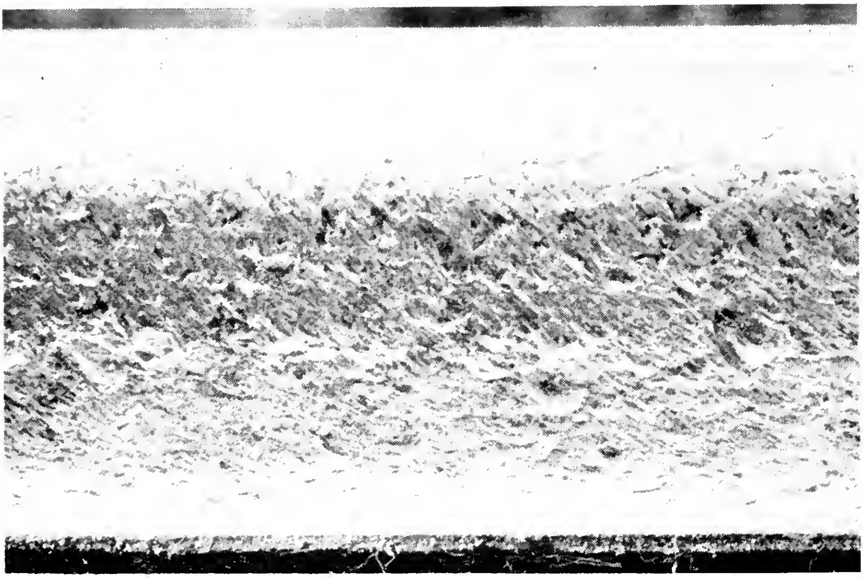


Fig. 1—Closeup of gage corner of high rail on 7-deg 30-min curve showing gouging and tearing of metal by the wheel flanges.

Fig. 2—High rail on 7-deg 30-min curve. Note metal flakes on rail base, tie plates and ballast.

Fig. 3—Box with trap door for collecting abraded metal flakes by diesel units separately from that abraded by remainder of train.

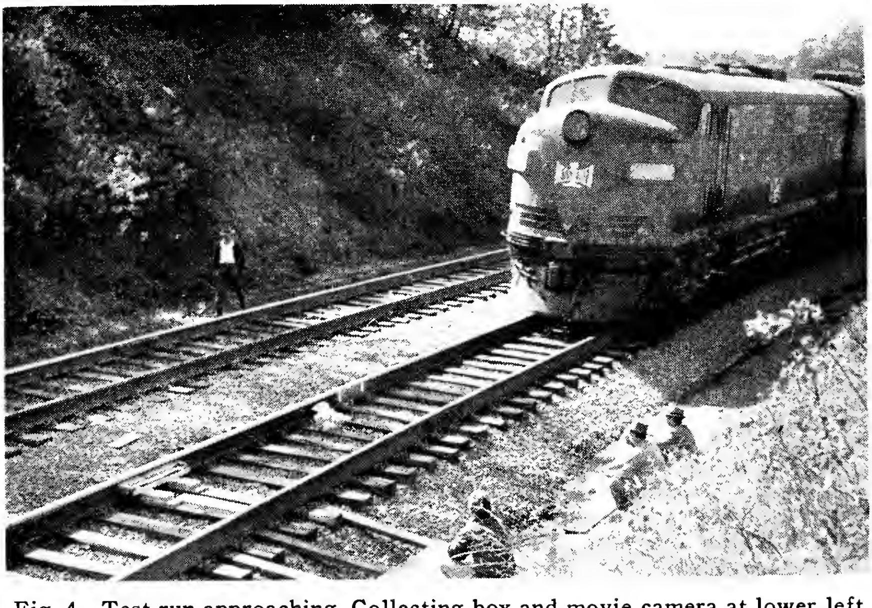


Fig. 4—Test run approaching. Collecting box and movie camera at lower left.

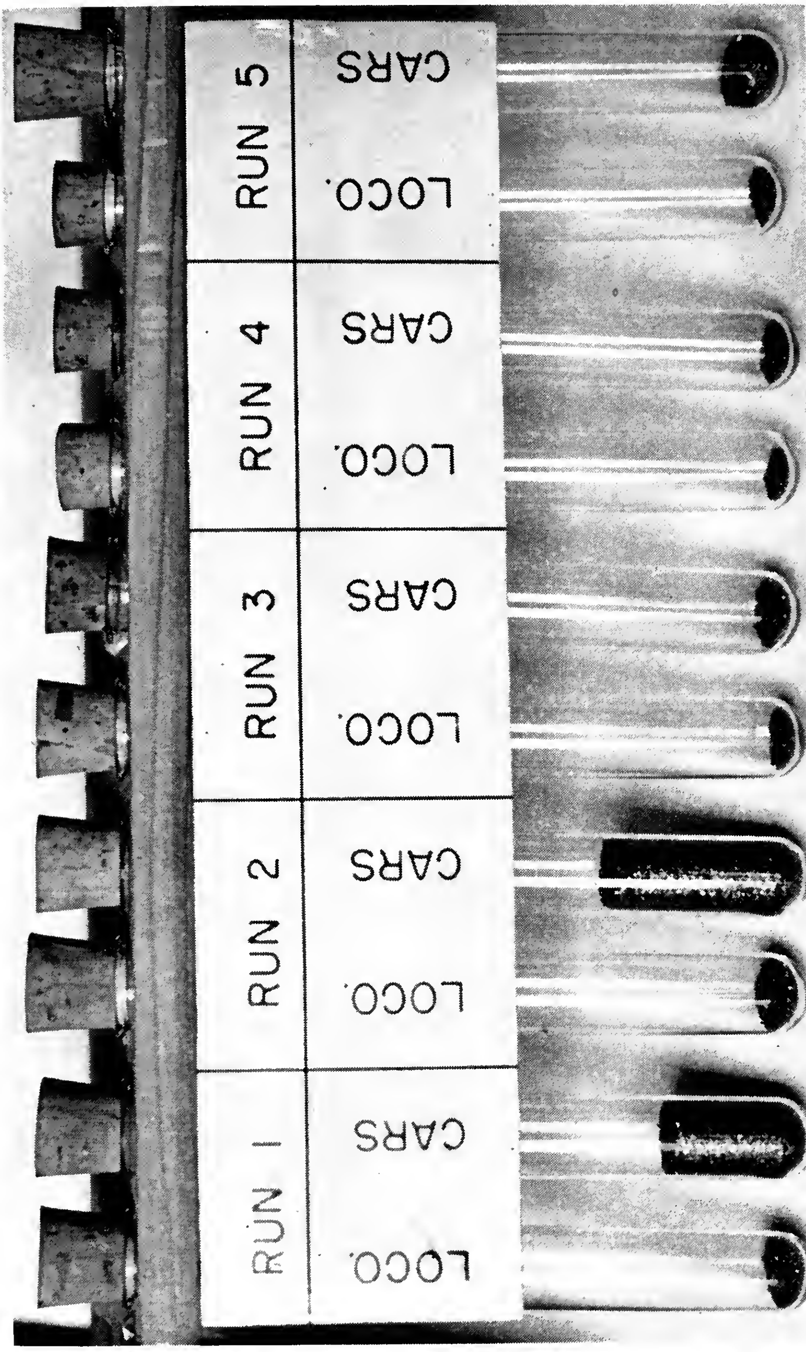


Fig. 5—Metal flakes from rail and wheels collected during five test runs. First test series.

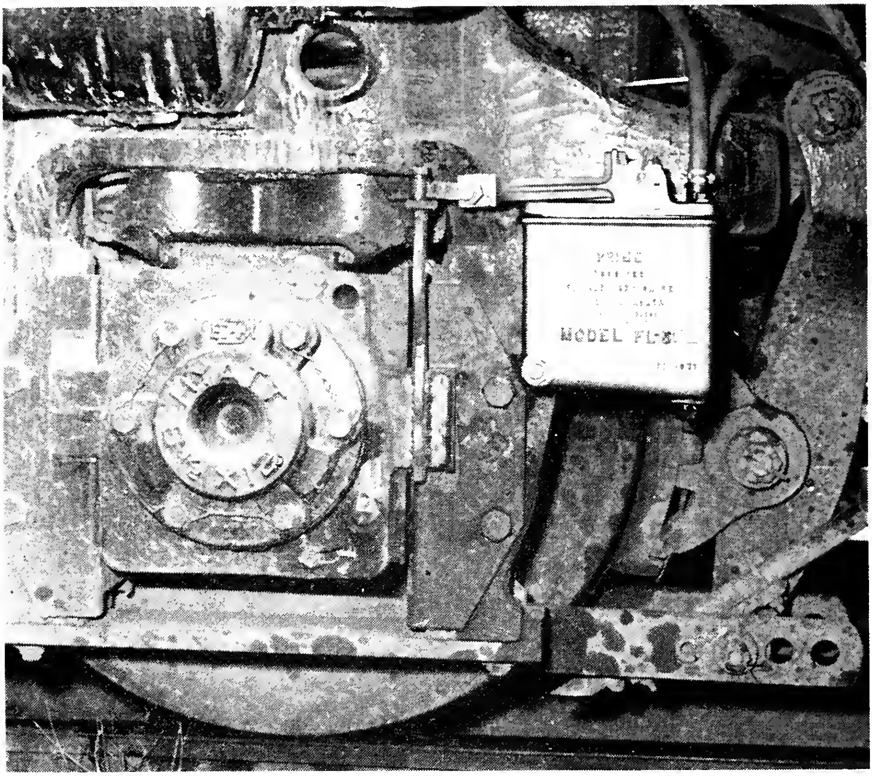


Fig. 6—Flange oiler used in tests. Each of the four diesel units used in the test runs were equipped with four tanks, each tank oiling the flanges of both wheels of one axle, all eight wheels of each diesel unit being so lubricated.

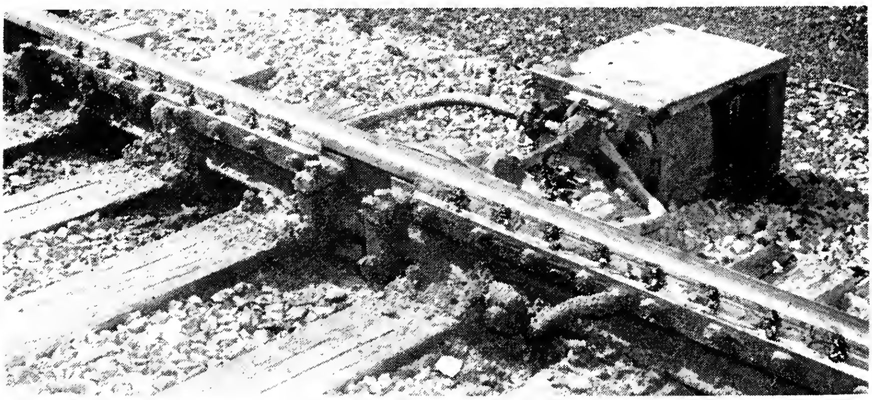


Fig. 7—Meco rail lubricator, installed about one mile ahead of the test location.

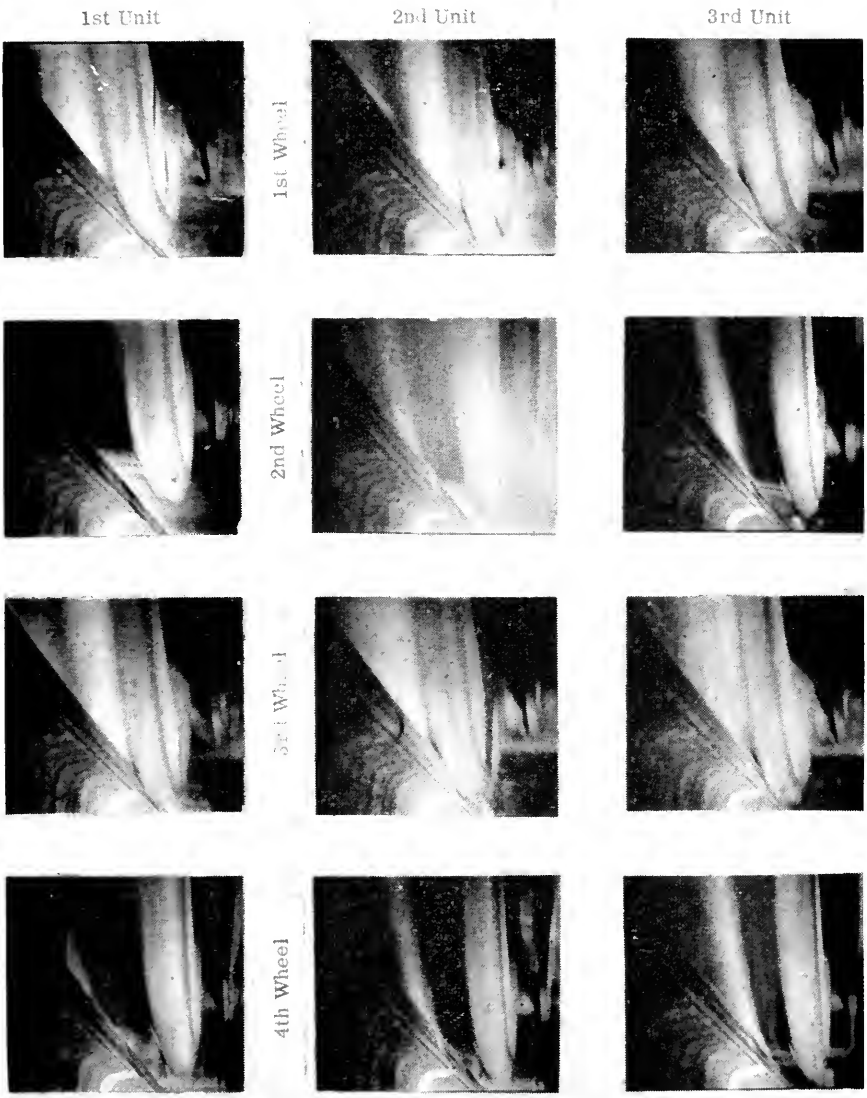


Fig. 8—Wheel flange positions of three head-end diesel units on high rail of 7-deg 30-min curve. Run No. 1 at 10 mph.

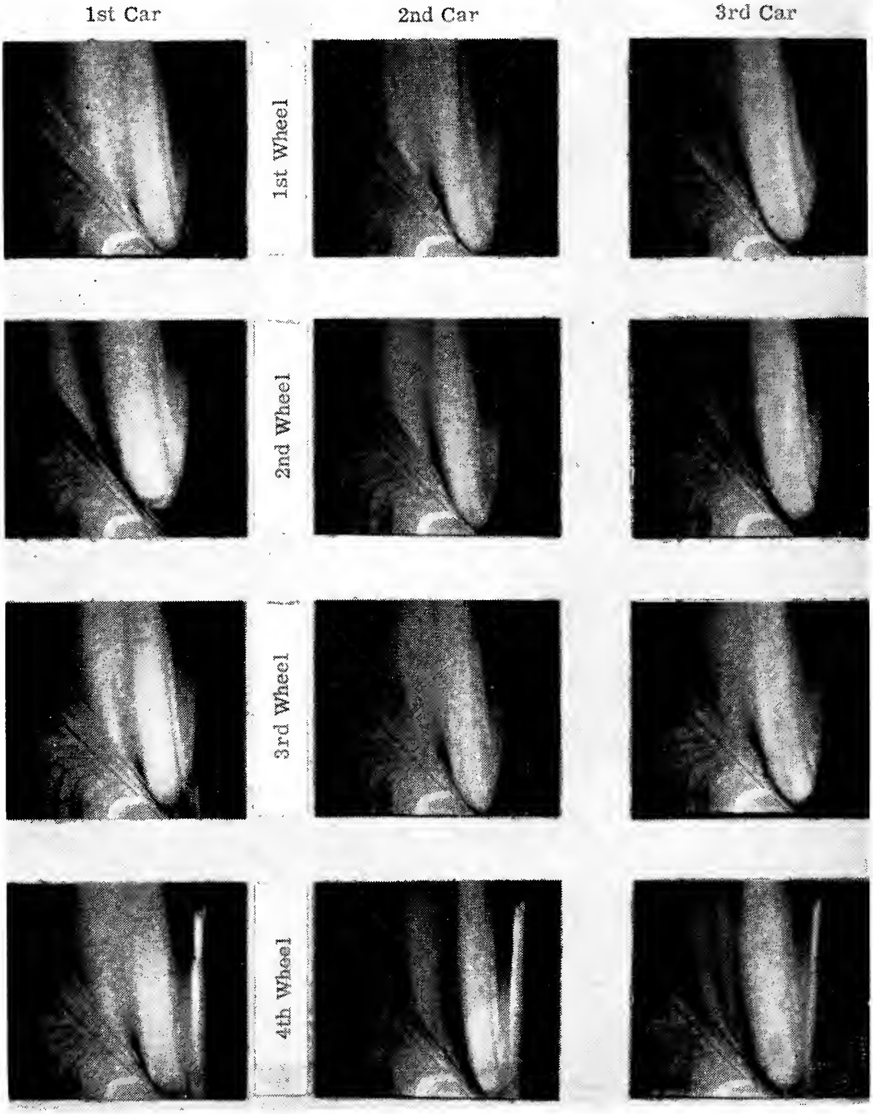


Fig. 9—Wheel flange positions of first three cars on high rail of 7-deg 30-min curve. Run No. 1 at 10 mph.

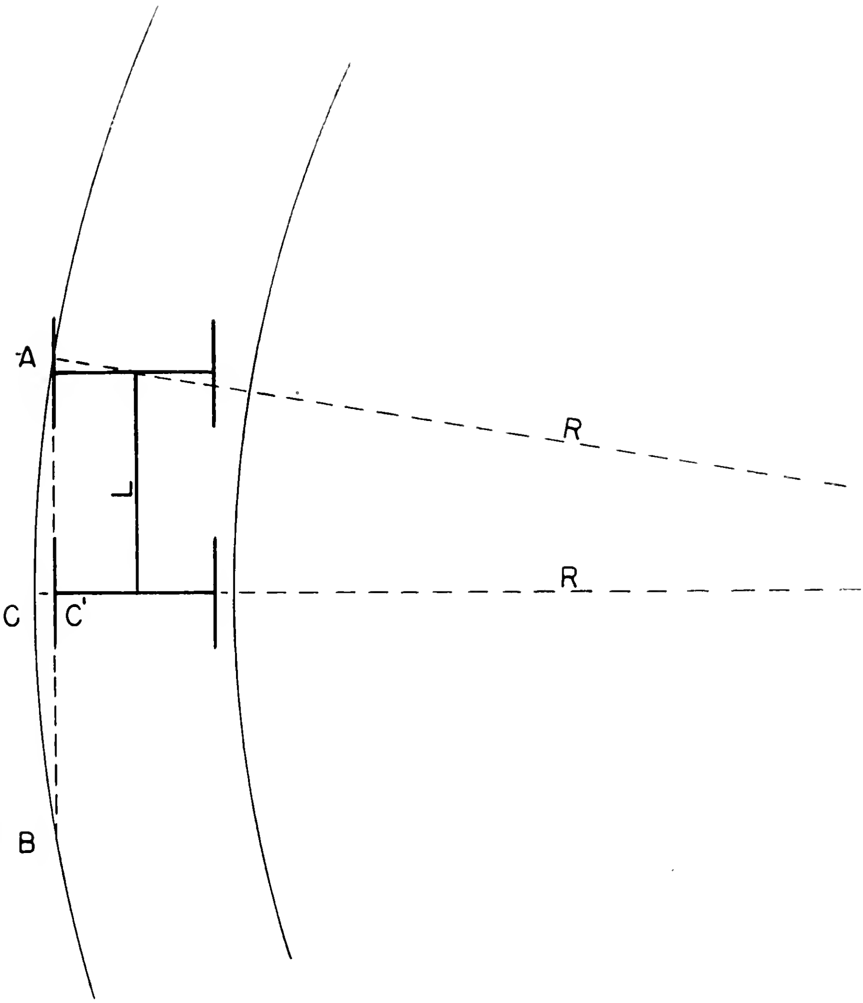


Fig. 10—Tracking characteristics of a 4-wheel truck.

Advance Report of Committee 5—Track

Assignment 8

Field Measurement of Forces Resulting From Rail Anchorage

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This report, submitted as information, presents the results of a field test which involved the measurement, under two-way traffic, of the dynamic forces exerted by rail anchors on the ties, of rail and tie movement, and also of the resistance of ties to movement in the ballast by static loads. Because this test has accomplished the primary objective of the assignment, your committee recommends that the investigation be terminated.

Measurement Under Traffic of the Dynamic Rail Creepage Forces Exerted on Ties by Rail Anchors and the Static Load Required to Move Ties in the Ballast, Near Kansasville, Wis., on The Milwaukee Road

DIGEST

This investigation was conducted for the purpose of developing fundamental information on rail creepage and rail anchorage. The tests were conducted on the single-track main line of the Chicago, Milwaukee, St. Paul & Pacific Railroad between Burlington and Kansasville, Wis. The track structure consisted of 112 RE rail with 4-hole joint bars, 24 ties per panel, and gravel ballast containing a considerable proportion of sand. The principal series of tests was conducted during the summer months and included measurements of rail movement, tie movement, and forces exerted by rail anchors on the ties with four different arrangements of rail anchorage under regular service trains. In addition, jacking tests were made on the rails to determine the resistance which the tie would afford to movement in the ballast for three arrangements of rail anchorage. Subsequently, the tests under traffic were repeated in the winter with one arrangement of anchorage only.

Analysis of the measurements has developed the following information with respect to these particular tests:

Resistance of the Tie

The resistance to movement in the gravel ballast of 1 tie anchored under both rails was on the order of 2000 to 2500 lb per rail. With every other tie so anchored, the resistance per tie ranged from 1500 to 2000 lb per rail, and with consecutive ties so anchored, the resistance per tie ranged from 700 to 1200 lb per rail. Somewhat higher values per tie, per rail were obtained with the "end-of-rail" method of anchorage. These represent summer values. Similar measurements were not made for winter conditions with frozen ballast.

Forces Exerted by Rail Anchors on Ties

It was found that several factors influenced the force that was exerted by rail anchors on ties in track. For simplification, these will be referred to as static forces (those existing between trains) and dynamic forces (fluctuating forces during the passage of a train).

(a) Static Forces

A static or steady pressure of the rail anchor against the tie was found to result from changes in temperature and from trackmen surfacing the track a short distance from the test section. Also, it was found that the passage of a train would normally leave a static force exerted on the ties in the direction in which the train had moved. The next train, if in the same direction, would tend to increase this force, but if in the opposite direction would tend to remove it and leave a static force in its direction of movement.

(b) Dynamic Forces

The forces that developed during the train passage were found to have three distinct characteristics or causes.

1. The depression curve of the rail between wheels was somewhat longer than the straight line distance between wheels. Accordingly, as each set of wheels passed and pushed down the depression curve or wave ahead of it, the rail tended to be moved slightly in the direction of traffic.

2. Because the rail anchor was located below the base of rail, there was a change in pressure exerted against the tie by pivoting action of the anchor rotating about the neutral axis of the rail during the wave action effect of the rail under traffic. For example, as a wheel approached the tie the rail was inclined so that the forward anchor pressed against the tie. When the wheel passed over the tie, the inclination was in the other direction and the pressure of that particular anchor was completely relieved. Theoretically this pressure would be completely relieved when the wheel was directly over the anchor at which time the anchor had resumed its vertical position.

3. As the wheel approached the anchored tie and pressure was exerted by the anchor on the tie due to the pivoting action, the top of the tie tended to be moved ahead or rocked slightly on its bed. However, as the wheel moved still closer to the tie the increasing vertical load on the tie tended to move the tie back to its original position. Actually, instead of the pressure against the tie being completely released when the wheel was over the anchor, there was some remaining pressure due to this return movement of the tie under vertical load.

The anchor pressures due to (2) and (3) above were generally substantially in excess of the pressure due to (1), and since all three occurred more or less concurrently, it was not possible in the test to isolate and definitely evaluate each of them separately.

Measured Anchor Forces

In the four different arrangements of anchors included in the test no outstanding or significant differences developed in the forces measured between the anchor and the tie. Measurements made under the rear five freight cars of long freight trains showed that the static anchor force developed was on the order of 200 to 300 lb per anchor per rail. The dynamic forces, however, were on the order of 500 to 600 lb per anchor per rail, so that the combined static and dynamic forces of the anchor on the tie ranged generally from 600 to 800 lb. The above represent average values, and occasional maximum values at individual ties considerably in excess of these amounts were measured.

The highest individual value for pressure of the anchor against the tie was 2930 lb, which occurred in the winter measurements. However, pressures as high as 2030 lb were measured during the summer.

Rail Movement

In these tests the amount of rail movement or creepage per 100 cars was least with 16 anchors per rail boxed on alternate ties. The amount of movement was more with 8 anchors per rail, but it did not increase in direct proportion to the inverse ratio of the number of anchors. With the three arrangements of anchorage included in the dynamic tests, using 8 anchors per rail, the order of effectiveness was as follows: (1) boxed in, (2) anchors placed on each rail against one face of tie only, (3) "end-of-rail" method.

Method of Anchorage

There was no information developed in these measurements which was in conflict with the results and recommendations derived from the service tests previously reported. The number of anchors required can best be determined by local observations as to whether the amount of anchorage provided is satisfactorily restraining rail movement. These tests confirm other tests that have been reported showing that more efficient anchorage per anchor can be obtained by anchoring every other tie rather than anchoring successive ties.

INTRODUCTION

Your committee was given its original assignment in 1943 for conducting an investigation leading to the determination of the proper "Number and Placing of Anti-Creepers for Various Conditions." Three 9-mile service test installations of nine arrangements of rail anchors were placed in single and double-track main lines of two large railroads using gravel and stone ballast. After the conclusion of the four year old service tests, your committee recommended methods for anchoring single and double track. (AREA Vol. 49, 1948, page 370). The recommendations were adopted for publication in the Manual of Recommended Practice by the Association at its annual convention, March 1948, (AREA Manual, 1953, page 5–5–4).

For several years some engineers interested in the subject of rail anchorage have desired to investigate the dynamic forces transmitted by rail anchors to the ties. In the summer of 1944, while measuring stresses in test rails on the Chicago, Burlington & Quincy Railroad, near Lathrop, Mo., for the purpose of designing the new 115-lb RE section, a pilot test was made with specially designed weigh bars for measuring the forces exerted on the ties by rail anchors. The equipment used appeared to be entirely satisfactory for a more extensive investigation.

Accordingly, after your committee had completed the above mentioned assignment, it was decided to have such an investigation made in view of the fact that there was practically no information available as to the forces exerted on the anchored ties by rail anchors under traffic.

PART 1. DYNAMIC TESTS UNDER TRAFFIC

GENERAL

Scope of Test

This part of the test was planned to include four arrangements of anchorage as shown in Fig. 1.* Schedule 1 had 8–8 anchors boxed on four alternate ties in each half

* All figures and tables are presented at end of this report.

of a track panel and is the same as the present AREA minimum recommendation for tracks carrying two-way traffic. Schedule 2 included only one-half as many ties boxed with anchors as Schedule 1. Schedule 3 had 4–4 anchors per rail, but they were not boxed against the ties. This anchorage was the same as arrangement G used in the Milwaukee Road, Kansasville to Burlington, Wis., service test. Schedule 4 had 4–4 anchors per rail boxed on one end of four consecutive ties near the joints, and is known as the "end-of-rail" method. This is the only schedule in which both ends of the same ties were not anchored. The foregoing tests were conducted in warm weather. During the following winter, Schedule 1 was repeated for the south rail only.

Description of Test Location and Traffic

The results of the previous service tests of rail anchorage indicated that more problems were involved with rail creepage in tracks with two-way traffic than with one-way traffic. It, therefore, was decided to conduct this test on the single-track main line of the Chicago, Milwaukee, St. Paul & Pacific Railroad, between Kansasville and Burlington, Wis., where one of the service tests was located. The panel of tangent track selected for the dynamic test measurements was located about 200 ft west of M.P. 20, approximately 2 miles west of Kansasville. The grade of the track at the test panel was 0.60 percent ascending westward. The location of the test house was approximately 300 yd west of a pronounced sag in the track profile. At the test site the previous arrangement of anchors in the service test was designated D, having 4–4 anchors for each rail which were boxed on both ends of four consecutive ties at the center portion of alternate half-track panels.

The track was laid with 1943 112 RE rail, 4-hole joint bars, 7½ by 11-in double-shoulder tie plates, 2 each of cut line and anchor spikes, and improved Fair anchors. The track had 24 creosoted oak ties per rail length and was ballasted with pit run gravel containing 40 percent, or more, of sand. The track had not been surfaced out-of-face since 1943 when the rail was laid. The 1943 rail was being surfaced elsewhere, but this work at the test location was deferred until these tests were completed as it was desired to make the tests where the ballast had not been disturbed recently.

During testing hours the regular daily traffic consisted of 2 passenger trains hauled by a 1-unit, 6-wheel truck diesel locomotive, and 2 time freights hauled by 2 to 4-units of 4-wheel truck diesels, both classes of trains being equally divided as to direction. A way freight train operated in one direction each day and was hauled by a medium size Mikado (2–8–2) steam locomotive having a small tender. In addition, there was an occasional extra freight train in either or both directions with steam power. Passenger train speed ranged up to 70 mph, while for freight trains the top speed was under 60 mph.

All trains operated by the test location normally, except (1) westward way freights reduced their speed in the sag and accelerated by the test house, and (2) eastward way freights made a hard service application of the brakes when approaching the test house, but did not come to a full stop.

TEST SET-UP

Track Devices

The location of the equipment used in the dynamic test panel for the various measurements is shown in Fig. 1. The weigh bars for measurement of the rail creepage forces transmitted by anti-creepers to the ties were designed and attached to the ties as indicated in Fig. 2, showing a tie equipped with only one weigh bar. The bars were mounted on the bearing blocks having a semicircular bearing surface so that they would function as a simple beam with free ends. The bars were of tool steel, but not heat treated. For each test schedule improved Fair anchors were applied to both rails in 10 track panels on each side of the test panel to correspond to the anchorage arrangement used with the weigh bars.

A rail deflectometer was provided for each rail after freezing the joint in the north rail to prevent rail slippage within the joint. Each spring was 1 in by ⅛ in by 17 in, and was attached to the top of a 2-in pipe driven in the roadbed about 4 ft. The Ames dial indicators (3-in travel) for observing the rail movement and position were mounted on 1⅛-in square bars, also driven 4 ft into the roadbed. The position of the wheels for each rail was obtained by having an SR-4 strain gage mounted on the gage side of the upper rail web in the south rail near the center of the test panel for the summer readings, and over the center of tie 15 for the winter measurements. The tie movement was measured in schedules 1, 2 and 3 by using a hack saw blade attached to a steel stake. Figs. 3 and 4 show the installation of three of the track measuring devices.

It was necessary to calibrate only the weigh bars in the laboratory as the deflectometers were calibrated in place in the field by turning the machine screw near the free end of the springs. This made it convenient to calibrate the springs quickly to the sensitivity desired. Two calibrations were required for the weigh bars because some of them were slightly bent in the static tests and in the dynamic tests during the winter. Four of the weigh bars were calibrated to the elastic limit, and the relation between the actual load and stress was found to be close to that computed for a simple beam. These four bars were then calibrated for stresses above the elastic limit, and the values were plotted. There was good agreement between the four curves, and the mean curve was used for converting stress to load on the weigh bar for loads over 2000 lb, equivalent to the extreme fiber stress over 45,000 psi.

Electronic Stress Measuring Equipment

For each rail the strain measuring equipment consisted of a 12-channel recording oscillograph, a 12-element strain gage balancing unit and amplifiers, and a regulated power supply having an oscillator to provide 5000-c current for the SR-4½-in wire resistance strain gages. The power was furnished by a 110-v, 60-c, 2.5-kw gasoline engine-driven generator. In all cases where two weigh bars were boxed against a tie under a rail, they were connected in the same channel so that the bar on the west side of the tie and carrying eastward forces would register in an upward direction on the oscillograms, and the other bar would register in the opposite direction. Clearances were provided between the bars and the thrust bolts in order to have only one strain gage operating at a time. This arrangement required 16 channels for the weigh bars in schedules 1 and 3, and 8 channels in schedules 2 and 4, at which time the 2 dynamometer tie plates were also operating.[1] In addition, 2 channels were required for the 2 rail deflectometers and 1 for the rail stress gage on the south rail for the wheel position marker, together with one channel for the tie movement deflectometer. The wheel positions were recorded on both oscillograms by connecting the rail stress gage circuit to a galvanometer in each oscillograph.

Each of the rail deflectometers had an SR-4 strain gage mounted on each side of the flat spring near the reaction block. These two gages, measuring equal compressive

[1] The report on the measurement of the magnitude and eccentricity of the tie plate loads was published in the Proceedings, Vol. 54, 1953, pags 1044-1046.

and tensile stresses in the same channel, were so connected as to add together in the tensile direction for an eastward rail movement, and in the opposite direction for a westward movement. The circuit for the tie movement deflectometer was similar to those described for the rail movement.

TEST PROCEDURE

Stress Records

Two oscillograms were taken for each train—one for each rail. Generally, in most tests involving the recording of dynamic strains under traffic, it is only necessary to have a base line immediately before and after the passing of a train. However, in this test it was desired to record any sudden rail movement and the resulting effect on the weigh bars before and after taking a record. Accordingly, base lines were also recorded when the approaching train was ½ mile from the test house, and also when the rear end had cleared the test panel by approximately the same distance. During the summer the oscillograms included the locomotive and first and last five cars of the freight trains, and all of the passenger trains. The winter records included all of each train for obtaining the total number of cars to avoid requesting this information from the railroad, which was necessary for the records taken in the summer.

Operation of Weigh Bars

During the summer testing the thrust bolts, which engage the weigh bars at mid-length, were adjusted each morning before the first train, which was generally time freight No. 75 WB. The clearance generally used was 0.005 in for each weigh bar. This practice was followed in all schedules, except No. 3, which did not have the weigh bars boxed on the ties. Except for a few runs at the beginning of schedule 3, for reversed movements, the thrust bolts were adjusted to engage the forward weigh bars prior to the run in order to be certain that the primary forward forces would be recorded by the weigh bars. If this had not been done, no record would have been obtained except that of releasing the static load from the rearward bars. For successive trains in the same direction, it was not necessary to adjust the thrust bolts because the preceding train left them engaged. The conventional anchorage in 10 panels of track each way from the test panel was left to function normally.

After each run it was necessary to determine, independently of the oscillograph records, the static load left on each forward weigh bar. This was accomplished by releasing one thrust bolt at a time and by reading the deflection on the oscillograph screen. The thrust bolt was then retightened to restore the same static load. From the static load measured after a test run, the static load on each weigh bar was then determined for the beginning of the oscillogram.

The winter test only included the south rail of schedule 1. Because the weigh bars did not have the strength to carry the loads anticipated in the winter when the ties would have much greater holding power in the partially frozen ballast, the thrust bolt clearance with the forward weigh bars was set from $\frac{1}{16}$ to ⅛ in for all freight trains. In addition, the static force on the backward bars, if any, was released before each train. In all of the dynamic force measurement tests, the sensitivity of each weigh bar channel was such that 1-in galvanometer deflection on the oscillogram was equivalent to 680 lb force on the bars.

Rail Movement

The rail deflectometers were calibrated after installation at each location by using the machine screw near the free end of the flat spring (Fig. 3). The sensitivity used was such that the actual rail movement was magnified 10 times on the oscillograms. The record obtained from this device was satisfactory for interpretation except for the rough cast iron wheels on the freight cars, which produced vibrations on the oscillograph trace.

The Ames dial indicators were used to observe the position and movement of each rail throughout each day. The dials (3-in travel) were read before and after each train and at frequent intervals throughout each day to detect the movement of the rails caused by changes in temperature of the rail, etc. A record of the rail temperature was also recorded throughout each day.

Tie Movement

The tie movement deflectometer was calibrated in the same manner as the rail deflectometers, except that the magnification on the oscillograms was only five times the actual movement of the tie (Fig. 4). The movement of the north end of anchored tie 7 was recorded in schedules 1, 2 and 3, except in schedule 3 it was necessary to move the spring to tie 9 for westward traffic because the anchors were not boxed in this schedule.

DISCUSSION OF TEST DATA

Typical Oscillogram

Fig. 5 is presented to show a part of the oscillograph record for a westbound time freight hauled by a 4-unit diesel locomotive at a speed of 33 mph. The figure includes for the north rail, eight traces for the rail anchor weigh bars, one each for the rail and tie movement deflectometers, and one showing the wheel positions at the bottom of the record. Base lines have been drawn on the record to denote the initial conditions, and to represent the dynamic zero for the weigh bars, which are designated by tie numbers (Fig. 1). For this westward train in schedule 1, forward or westward forces and movements are recorded downward on the record. Deflections on the weigh bar traces below the base lines represent the primary forward forces added by the passing wheels, and those above the base lines are dynamic partial releases of the westward static forces on the weigh bars. The initial westward static force on each weigh bar is indicated for each trace near the left end of the record.

Run 49 was the first one of the day and the westward static loads on the weigh bars were caused by a westward movement of the rail of 0.05 in after the thrust bolts were set for the day's testing. Bar scales have been added to the record to show the extent of the forces and movements. The wheel arrangement for the first 3½ units of the diesel locomotive has been shown at the top of the record for tie No. 5. The wheel positions, using other offsets, are also shown for the rail and tie movement deflectometers.

It will be observed from the trace for weigh-bar tie 5 that the downward peaks occurred ahead of each wheel and the partial releases were behind the wheels. The longitudinal movement of the rail (on level with its base) is shown by the rail deflectometer trace. It has a consistent pattern of apparent forward movement ahead of each wheel and backward movement behind each wheel. The sequence of the movements of the north end of tie 7 is somewhat similar to the rail movement, except for more irregularity. For this record and others taken during the summer, the total tie movement for a train was about the same as the corresponding rail movement. The pronounced forward (downward in Fig. 5) movement of tie 7 occurred between the trucks of each diesel unit and between the two B-units where there was a wide spacing of the trucks. From the record, it will be noted that neither the rail nor the tie had much progressive forward movement under 3½ units of the diesel. Under a locomotive pulling hard, the traction forces oppose the forward progressive movement of the rail caused by the creepage force which is associated with flattening the rail wave ahead of each wheel. It will be of interest for a later discussion to note that each trace has a pattern in good agreement with the wheel spacing.

The total movement of the north rail in this run with 93 cars and 4 diesel units was ¼ in. At the end of this run, weigh bars 3, 5 and 7 had less static load and the other five had more westward static load. For example, the high initial westward static load of 570 lb on tie 5 was dissipated to 220 lb, while tie 17 had the largest increase from 70 lb to 430 lb. These variations, as well as the differences in the magnitude of the dynamic forces of the eight weigh bars shown in Fig. 5, demonstrate the wide variations in the forces transmitted from the rail to the ties by the anti-creepers. At the end of this record and those of other long freight trains, the rail and tie movement traces reached an equilibrium position, except for back and forth deviations, and the patterns of dynamic forces for the last few freight cars for each trace were uniform for successive cars.

GENERAL DISCUSSION OF THE OSCILLOGRAMS

Because of the complexity and variability of the forces and movements of rail and ties measured during the summer and winter test periods, no attempt will be made to discuss the individual characteristics of each test record. The records have been categorized as to initial conditions and preceding train movements, and will be discussed on that basis.

Summer Test Records—Constant Speed

All of the records in the summer test, with the exception of schedule 3, had the same basic form for each trace representing a box-anchored tie. The test procedure was to set the thrust bolts with a given clearance before the first train in the morning and allow the traffic during the day to build up static force on the weigh-bar ties as in the case of conventional anchors. Schedule 3 again was an exception to this rule, because the weigh bars were not boxed against the anchored ties. The records reflected the conditions which were imposed upon them through variations in traffic, temperature of the rail, relative position of the rails and ties, etc. Records which were taken of constant-speed movements usually showed little or no movement of the rail ½ mile before the train or immediately prior to the locomotive. There was evidence of some back-and-forth movement of the rail under the locomotive, but most of the time the effect of traction offset any progressive forward movement. If the rails were in a free position to move before the run, then the actual progressive forward rail creep started immediately following the locomotive and continued at a fairly constant rate per car to where the record was stopped at the end of the first five freight cars. The amount of movement obtained during the period while no record was being taken could easily be accounted for by measuring the shift of the trace before and after the break in the record. Generally, for the longer freight trains, the force patterns of the weigh bars had become uniform and the rail had ceased to move progressively forward for the last five cars. Full-length records were taken under the short passenger trains, which usually showed a continuous progressive rail movement under the cars. In comparing the rail movement per car, it was found that there was little difference between six passenger cars and the same number of freight cars next to the locomotive. For successive train movements in the same direction, there was a marked tendency for the rail movement to be progressively less for the following trains because the rails were approaching their limit established by each method of rail anchorage outside of the test panel. As will be shown in the last part of Table 2, there was a definite range or amplitude of rail movement for each of the four methods of rail anchorage. The rail assumed a fixed position but never showed a backward movement extending for several car lengths, which occurred during certain runs in the winter test.

In general, the oscillograms showed that the total forces increased on the anchored ties in the case of two or more runs in the same direction. This can be attributed principally to the amount of forward static load which each train left imposed upon the weigh bars for the succeeding run. Under a reversal of traffic, the rail was usually in a free position to move forward. The ties apparently were more easily pushed or tilted under these circumstances. It will be noted in Table 1 on maximum forces, that schedule 2 with the greatest number of reversals had the smallest forces, and that schedule 3 with the fewest number of reversals had some of the highest forces.

The forces at the beginning of a reversed movement in some instances showed only the dissipation of static loads on the rearward anchor of a boxed tie applied previously by the preceding train in the opposite direction. The force pattern of the rearward weigh bar assumed a shape quite similar to that of the forward bar, except that the force peaks trailed the wheels instead of leading the wheels. After a small forward rail movement, the rearward bar was disengaged by the thrust bolt and the forward bar was engaged with resulting forward primary forces resisting rail creepage. The rapidity with which this action took place depended upon the amount of static load that the rear weigh bar had built up and the degree of rail movement occurring. The elapsed time between the two events varied because of the variation in clearances between the thrust bolts and the weigh bars. The individual wheel peaks, which indicated the force exerted on the weigh bar through the angularity of the rail, occurred ahead of the wheel on the forward weigh bar and behind the wheel on the rearward weigh bar.

In schedule 3, the ties were pushed in the ballast in one direction only because of the anchors being placed on only one side of the tie. For the first few runs in this schedule the forward thrust bolts were not adjusted to engage the weigh bars for a reversed movement. An examination of those records for the reversed movements revealed that for the short passenger trains and the greater portion of the long freight trains, practically no forces were recorded by the weigh bars. This demonstrated the ineffectiveness of both the weigh bars and conventional anchors when not boxed against the ties for anchoring rail against two-way traffic. Occasionally traffic movements succeeded each other in the same direction during this schedule. In the event of this, the forces on the ties became quite large. This occurred only after the ties had been pushed in the ballast far enough in one direction to assume a very firm position.

Analysis of the shape or form of the actual weigh bar traces under the locomotives and cars during the summer tests demonstrated the effect of the static loads which the anchors imposed upon the ties, the angulation of the rail under moving wheels, the reaction of the tie under dynamic impulses, and the relative motion of the rail. These were the main factors which influenced the appearance of the traces on the oscillograms. The peaks representing the instantaneous applied forces occurred at definite distances in front of the wheel when the forward weigh bars were engaged. Following the first wheel peak there was a partial release of the dynamic load, followed by another force peak and then a quite sudden release to the dynamic zero base line between trucks of the locomotive. This pattern repeated itself throughout the locomotive and cars with slight modifications. Actually, the correlation of measured dynamic weigh bar forces with the angularity force of a depressed rail in Fig. 6 showed that a full release was not obtained between wheels of trucks of a locomotive. The explanation for this condition in the summer tests was that the relative movement of the tie tended to offset the full effect of any theoretical release due to angulation of the rail.

In studying simultaneous movements of the tie and rail, it was noted that the tie moved backward for a short period as each wheel passed over it. This was also apparent under a freight or passenger car. The progressive movement of the rail, which occurred during the run, appeared on the weigh bar traces as a cumulative change in the static base line. As the static load increased on the weigh bar while the train moved over the test section, the corresponding dynamic peaks assumed a greater magnitude. When the rail stopped its progressive movement, keeping the static load constant, the dynamic pattern leveled off. On certain occasions the total load upon the weigh bars increased due to a temperature change causing rail movement. Several oscillograms demonstrated the effect of movement of the rail caused by a surfacing gang working near the test section. In these cases the static load imposed upon the weigh bars was quite large and resulted in a large total force under the front of the locomotives. However, the weigh-bar ties were moved forward and a large portion of the static load was dissipated by the first few passing wheels.

Accelerating and Braking Records

In order to observe the results of trains accelerating and braking, it was decided to have the westbound local freight train accelerate past the test section and apply brakes on its return trip. The accelerating runs showed little increase in speed because of the adverse grade. The trains braking were not required to come to a full stop, but the records showed some deceleration of speed. Generally, there were no very large forces developed on the weigh bars. However, there were some significant differences in the rail movement under both conditions in comparison with constant-speed records.

Because of the additional tractive effort produced under an accelerating engine at low speed, the rail showed an initial movement backward ahead of the locomotive. Following this movement, which occasionally was significant in magnitude, was the usual back-and-forth rail movement pattern under the locomotive. After the passing of a few cars, the rail assumed a moderate progressive forward movement. This smaller rail movement under trains accelerating, generally prevented the weigh bar forces from becoming large; however, due to other conditions, some of the maximum forces for a schedule were developed under these accelerating runs.

In analyzing an oscillogram during which a brake application occurred, there was evidence of interesting variations developed with regard to rail movement. Generally, the rail moved forward farther in front of the locomotive than for a constant-speed run. Under the locomotive the rail showed a perceptible progressive forward movement, which was uncommon for constant-speed runs. If the rail were in a free position to move forward, the braking runs showed more total rail creepage per car than did the other runs of comparable train length. There was evidence on only one record that braking caused higher dynamic forces on the weigh bars than did non-braking runs with comparable conditions. The conclusion was reached that the total weigh-bar forces measured in the braking runs were not greater than that for constant-speed runs. Larger forces would have been developed if the train had stopped on the test panel. This was avoided in order to minimize train delay.

Winter Test Records

The purpose of the winter dynamic test was to develop information on the rail creepage forces which were transmitted by the anchors to ties in partially frozen ballast. This was accomplished by taking oscillograms of the weigh-bar forces in the south rail only, using the rail anchorage of summer schedule 1. Since it was possible to over stress and permanently bend the weigh bars during the winter, it was decided to set the thrust bolts with a clearance of $\frac{1}{16}$ in to $\frac{1}{8}$ in before the passing of each freight train. The bolts for the short passenger trains, however, were set up so as to contact the weigh bars before each run. The results obtained from this winter phase of study were significantly different from those in the summer.

The movement of the rail in the winter tests can best be described by breaking it down into three general categories: (1) steady, with little progressive movement; (2) gradually increasing forward movement; and (3) alternately progressive forward and backward movement under the train.

A relatively few records had little or no progressive forward rail creepage during a test run. This generally occurred under the short passenger trains when the forward weigh bars were engaged by the thrust bolts prior to the run and the rail had reached its forward limiting position. With the exception of the progressive rail movement, these passenger runs showed the greatest tendency to follow the general, overall appearance of a comparable summer record. Because the forward thrust bolts were engaged at the onset of each run, these trains developed higher total forces than some of the freight traffic.

The remaining two categories possessed one thing in common. Both types started out with progressive forward rail movement. This extended from the engine back through a variable number of cars. The movement was usually rapid and accompanied by little indication of forces on the weigh bars due to the clearance on the thrust bolts in the test panel. At this point on the records, the movement either progressed slightly, leveled off with a small amount of force showing, or proceeded to move backward for a few cars and then forward. The appearance of this action on the force patterns resembled very closely that of pulsating forces, decreasing like the displacement of a damped spring. Actually, two conditions were responsible for this response; the rail had been moved forward to close proximity of its limiting position, and the ties were offering much more resistance to creepage in the winter because of the partially frozen ballast.

Two runs in the winter test schedule showed an unusual amount of forward progressive rail movement, together with very high total forces. This was caused by having a smaller clearance on the thrust bolts prior to the runs, and thus engaging the weigh bars near the front end of the long trains. However, the rail did creep extensively and built up a great amount of static load on the ties. It should be remembered that there were 10 rail lengths of track on each side of the test panel which were anchored in the same manner in order to give continuity of the anchorage. These other anchors controlled the rail creepage even though the anchors in the test panel were not always functioning.

The forces recorded during the winter never attained any great magnitude except in the case of the aforementioned runs. This does not mean, however, that there were no forces present. On the contrary, in the case of the two previous runs the forces became so large that the weigh bars were bent. There was a striking difference in the component parts which constituted the total force on a weigh bar between winter and summer records. The summer tests developed constantly increasing static forces on the ties with corresponding increasing dynamic forces. The ties were relatively free to tilt and be pushed in the ballast, which tended to limit the amount of static load each tie could resist. The modulus of track support in the summer was smaller and more deflection and angularity of the rail were obtained. This situation made it more opportune to obtain higher dynamic forces. Considering both passenger and freight trains, the ratio of dynamic forces to static forces was twice as large in the summer as it was in the winter. That is to say, with the same amount of static imposed upon a weigh bar in the summer and winter, the dynamic force which is superimposed on this static force tended to be approximately twice as large in the summer compared with that in the winter. The reason for this difference was the larger modulus of support, tending to give less deflection and angularity, and the tight ties in the partially frozen ballast which could tilt backward against the forward weigh bars much less than during the summer measurements.

The appearance of the weigh-bar force patterns in the winter test showed a different pattern representing the release of applied loads on the ties. In the summer records, immediately after the passing of the front truck of a car, the release of the load occurred quickly and was sustained longer because of the tie movement in the ballast. The summer records showed a greater tendency toward a full release for a longer period of time than did the winter records where the force built up gradually, but distinctly, immediately following the release behind the second wheel of the front truck. In some instances in the winter test, full release of the dynamic force under a car did not occur.

A study of the simultaneous rail and tie movements from the summer test oscillograms revealed several reasons for the different reactions. The movement of the rail was taken from the record and superimposed over the tie movement. It should be remembered, however, that the rail movement was not taken at a thrust bolt anchor which was actually functioning against a tie. Nevertheless, a good comparison showed that between cars and axles of a truck the ties in summer actually tilted backward as the wheel had passed over it. This kept the release angle from taking its full effect. In the case of a static load on the weigh bar, the anchored tie was tilted forward before the train approached. Upon application of the force by the first wheel of a group of closely spaced wheels, the tie was tilted forward more before receiving the major portion of the vertical load. This dynamic action was independent of the static condition of the tie. As the wheel passed over the tie, it tilted backward, keeping the weigh bar in contact with the thrust bolt and permitting only a partial release of the dynamic force. Although tie movement was not measured during the winter, it is assumed that there was sufficient tilt of the anchored tie to prevent a full release of the dynamic forces between cars or axles of a truck. The movement required would be less than 0.01 in, and that is judged to have been possible in the partially frozen ballast. Each sunny day the ballast was thawed for a depth of 3 or 4 in.

It was noted that the actual progressive forward movement of the rail occurred immediately after the first truck of a car or diesel locomotive had passed over an anchored tie. The winter records developed a pattern of forces which more closely approached the theoretical pattern presented in Fig. 6. The first wheel in each group under 4-wheel truck diesel units had the largest force, and the forces caused by the following wheels were smaller. The partially frozen ballast prevented the ties from moving and reduced the tilting to a small amount, thus providing a high degree of rigidity for the anchored ties upon which the computed weigh-bar forces were based.

Correlation of the Dynamic Forces with the Wave Action of the Rail

By referring to the oscillogram specimen in Fig. 5, it will be observed that all of the traces had definite patterns with respect to the wheels. At first, the explanation for the patterns of the forces on the weigh bars and the shape of the rail movement trace was not evident. In the meantime, analyses of the weigh bar forces were made for comparable trains in each of the summer schedules. These data definitely indicated that the forces transmitted to the weigh bars by the rail anchors in the four schedules with different arrangements of anchorage were not appreciably influenced by the number and spacing of the anchors. It was then realized that a study of the dynamic and static forces developed by the weigh bars would not serve as a satisfactory yardstick for judging the relative merits or effectiveness of the different anchorage arrangements. It appeared that the dynamic forces on the weigh bars and the apparent back and forth movement of the rail were the result of the change in angularity of the rail depression curve, or the wave action of the rail. The thrust bolts engaged the weigh bars 1⅜ in below the rail base, and the rail deflectometers were engaged at a point level with the bottom of the rail base. Assuming that the rail was bending about its horizontal neutral axis, lever arms swinging through the angular changes of the wave of the rail would then be 4⅜ in and 3 in from the neutral axis for the weigh bars and rail deflectometers, respectively.

The foregoing analysis is presented graphically in Fig. 6. The rail depression curve, as shown in the lower portion of the figure, was computed in accordance with the theory of the rail being supported on a continuous elastic foundation, which was published in the Proceedings, Vol. 19, 1918, pages 878–896. Additional information pertaining to the computation of rail stress and depression was included in Bulletin 447, Sept.–Oct. 1944, pages 43–50, but was omitted from the Proceedings, Vol. 46, 1945.

The location and width of the zones of maximum angularity of the rail depression curve were obtained by computing rail depression values at close intervals along the rail. It was determined that there were no sharply defined points of contraflexure in the curve, and that for all practical purposes the maximum angles were sustained by the rail over a distance varying from 3 in to 30 in, depending upon the effect of the number and spacing of the diesel wheels. The zones of maximum angularity for the A-unit and the front truck of the B-unit diesel have been designated in Fig. 6 as "f" for the maximum forward dynamic forces exerted on the weigh bars ahead of each wheel, and as "r" for the rearward forces behind each wheel. At points where the tangents to the rail depression curve are horizontal, there is no angularity of the curve, and theoretically, the force on the weigh bars caused by the angularity of the rail should be released.

From the maximum angles of the forward zones, the 4⅜-in lever arm of the thrust bolts contacting the weigh bars, and the flexural characteristics of the weigh bar, the forces were computed for each wheel. These calculations were based on rigid construction, and such items as tie tilt, deformation of the anchor, the thrust bolt, and the tie under the bearing blocks were excluded. The computed curve for the forward dynamic forces is shown in the upper portion of Fig. 6. For this curve the maximum force values were plotted on the medians of the zones of maximum forward angles, and zero values were shown for each horizontal tangent of the rail depression curve. These points were connected with curves drawn arbitrarily. For comparison of the theoretical force curve with that measured, a record without static load on the weigh bar was selected for plotting in the figure. A comparison of the actual and theoretical force curves indicates good agreement as to position of the peaks. There is poor agreement between the magnitude of the actual and computed dynamic forces on the weigh bars, particularly for wheels 1A and 3A. It was not surprising that the forces did not check as well with the calculated magnitude as the computed position ahead of the wheels. There was considerable variation in the track play between the rail base and the ballast below the bottom of the tie because the track had not been resurfaced for several years. In track, the play between the rail base and the tie bed will directly increase the actual rail depression and thus greatly affect the angular changes of the theoretical curve. Furthermore, it has been found in other tests that the characteristics of the elastic foundation of track vary appreciably from tie to tie. However, many of the summer records and a few of the winter oscillograms showed the larger forces at wheels 1A and 3A.

Only partial releases of the dynamic forces occurred directly under each wheel and between the axles of all trucks of diesels and cars, and between cars and diesel units, except for the larger wheel spacing between two B-units, back to back. Full releases of the dynamic forces were obtained between the trucks of all diesel units and cars in the summer records because the ties could move or tilt in the ballast when unloaded. However, this was not generally true for the winter records, because of no tie movement and little tilting of the tie in the partially frozen ballast.

The summer records showed distinctly that as the rear truck of a car reached a weigh-bar tie, the tie would tilt backward and prevent a full release of the dynamic force, until the lead truck of the following car had cleared the anchored tie. However, with the greater wheel spacing between cars, such as passenger cars compared with the smaller spacing between freight cars, the releases were relatively larger but not complete. It is possible that the pattern of rail base movement, taken at a point between ties where the rail was free locally to follow the theoretical rail depression curve, would not necessarily be identical to the pattern at a thrust bolt anchor which was restrained by the anchored tie. For the winter measurements, it is assumed that the ties could tilt sufficiently to delay the full release until the force of the following wheel was initiated. This would require movement of less than 0.01 in.

It is evident that the measured dynamic forward forces exerted on the weight bars by the rail anchors were partially due to the angular variation of the wave action of the rail. The magnitude of these forces was influenced also by the backward tilt of the tie, which is associated with the magnitude of the static force, and the resistance of the tie to movement in the ballast. The rail creepage force at each wheel, caused by rolling out the convex upward curvature in the rail ahead, was masked out. The effect of this force can be observed from the records of the rail deflectometer where the rail moved progressively forward between the trucks of each car until stopped by the anchors outside of the test panel. The accompanying progressive forward tie movement in the summer occurred quickly after the passing of the trailing axle of the front truck of a car or diesel, as the forward dynamic force on the weigh bar of the same tie was released.

COMPARISON OF MEASURED FORCES

Comparable Trains

A comparison of the average rail anchor weigh-bar forces was developed for the rear five cars (excluding the caboose) of time freight train No. 86 EB in each of the five schedules. In all cases, train No. 86 EB was preceded by a train in the opposite direction. The forward forces have been summarized and shown graphically in Fig. 7. Each of the bars in the figure having a time number shows the average of the forces measured under the 20 axles of 5 freight cars. Although this comparison was based on comparable train operation in each of the five schedules, it is evident that the rail creepage forces as transmitted to the ties by the anchors were not appreciably influenced by the number and spacing of the rail anchors in the dynamic test panel. The forces were highest in the winter schedule because the ties could not move in the ballast as in the summer schedules. Relatively large amounts of static were built up on the weigh bars by a few of the long trains in the winter schedule. This related in relatively smaller dynamic forces than those obtained during the summer measurements. In addition, other analyses were made to compare the forces in the five schedules, and none was satisfactory for judging the relative merits of the four methods of rail anchorage in the test panel. In view of the foregoing develoument, it is believed that a comparison of the maximum values of total force on the weigh bars will be of greater interest.

Maximum Measured Rail Creepage Forces

The maximum forces transmitted to the ties by the rail anchors will be of interest to those concerned with maintenance of way and the manufacturers of rail anchors. The largest forces measured on the weigh bars occurred in the winter, but some values were relatively high during the summer because of sudden rail movement caused by changes in rail temperature or from surfacing the track out-of-face near the test section, or other reasons.

For each test schedule, the three largest total weigh-bar forward forces were obtained from the oscillograms for both the locomotives and cars, separately. This information has been summarized in Table 1, consisting of two parts: one for locomotives, the other for the cars. It will be observed in the table that some tie numbers predominated in having the maximum forces. There was no relation between the magnitude of the forces and train speed. Total weigh-bar forces under 1000 lb are not considered large ones. In some categories there were no large forces recorded, but the maximum values were included as a matter of information.

Large forces were not exerted on the weigh bars under the locomotives unless the thrust bolts were engaged with the weigh bars, and an initial static load was present prior to the train. Generally, under a locomotive, there was no progressive forward movement of the rail which built up a static load on the weigh bars. The effect of flattening the depression curve of the rail tending to move the rail forward was offset by the effect of tractive force on the rail. In the winter schedule, thrust bolt clearance on the weigh bars was set from $\frac{1}{16}$ to $\frac{1}{8}$ in for the longer trains to avoid bending the weigh bars. Consequently, most of the records showed no forces under the locomotives because the thrust bolts had not engaged the bars. The maximum values occurred in run 16–W, EB passenger train, because the thrust bolts were left engaged prior to the run. In runs 61, schedule 1, and 45, schedule 3, both north rail, high forces were recorded under the locomotives because of a sudden jump of the rail which placed large initial static loads on the forward weigh bars of the ties shown in the table. The rail jump was evidently caused by an extra gang surfacing track 10 rails west of the test panel. No large forces were recorded under the locomotives in schedule 2 because each train operated in the reverse direction of the preceding one, except in one instance (run 23), which also had no initial static load on the weigh bars due to a relieving rail movement prior to the run. For reversals of traffic, an appreciable part of the rail movement was required to dissipate the rearward static force and then engage the forward bar with the thrust bolt. These conditions were not conducive for creating large forward forces under locomotives.

The highest forces measured in the tests were recorded under freight cars of run 13–W in the winter (see Part 2 of table). For this long train, the forward thrust bolt clearance was reduced to $\frac{1}{16}$ in. Extremely large static forces were exerted on the weigh bars, and all of the eight weigh-bar traces, except one, swung off the oscillogram. The maximum force of the trace left on the record was 2930 lb. The trace next to that one showed a force of 3250 lb at the edge of the record. After this run it was observed that all of the weigh bars were slightly bent, and two of the eight anchors having thrust bolts had slipped on the rail base. This occurrence should not be interpreted as indicating the holding power of the new Fair anchors. During the conduct of these tests, those anchors having the thrust bolts attached were applied to the rail 10 to 15 times, which tended to reduce their gripping strength on the rail base.

For the other runs in Part 1 of this table with values over 1000 lb, the larger forces under the locomotives were caused by the presence of static force on the forward bars prior to the arrival of the train. Similarly, for the other runs in Part 2 of the table, the larger forces under the cars were attributed to the presence of a static force on the bars when the rail was free to run. Schedule 3 had the additional advantage of recording large forces because the anchored ties were moved in only one direction, and developed higher resistance to movement, the maximum values all occurring after the tenth run in the schedule. In general, the weigh-bar forces were larger in schedule 3 for the foregoing reason and because the forward thrust bolts were adjusted to engage the bars for each reversed movement. This was necessary in order to obtain a record of the primary forces. Otherwise, the only information recorded on the oscillograms would have been the dissipation of the rearward static force from the ties anchored to resist rail creepage on the wrong direction, which would have had little significance. Generally, the forces were smallest in schedule 2 because all except one train were reversed movements.

It cannot be stated with certainty, but it is believed that these high forces measured on the weigh bars can also be imposed on the conventional anchors, particularly when the ballast is frozen. Stripped joints may even cause greater forces to be exerted on the anchors near the open joint. However, in track, if the anchors are applied properly, there is a tendency for the forces to be equalized, either by crushing the side of a tie or by moving anchored ties in the ballast when some of the anchors are stressed more than the others. Obviously, this is not true in the case of sudden jumps of the rail or stripped joints.

All of the high forces measured are well below the holding power of most types of rail anchors when new.

RAIL CREEPAGE

Characteristic Movement

The record from the rail deflectomers was taken level with the bottom of the rail base between ties 14 and 15, several inches from a thrust bolt anchor. For all practical purposes, it is assumed that the rail movement, including the back and forth deviations, at a thrust bolt anchor was similar to that shown by the above record. From Fig. 6, it will be observed that most of the forward rail creepage under a diesel unit can be attributed to flattening out the long rail wave between its trucks. Because the records showed that the rail and tie moved backward under the trucks, the progressive forward movement could only occur between trucks of a diesel unit or a car. Therefore, since the rail was restrained from creeping forward until the front truck of a car had passed an anchored tie, it is evident that the forward rail creepage under a given car was that which had accumulated under the rear truck of the car ahead and also under the front truck of the car in question. In other words, the forward rail movement under a car consisted largely of the creepage caused by the next preceding car. This was confirmed by the fact that the records showed a forward progressive rail movement after the last car of a train had passed the rail deflectometer.

Magnitude of Rail Movement

Comparative rail movement in the five test schedules is perhaps the most significant information obtained in the dynamic tests for judging the effectiveness of the four arrangements of rail anchorage tested. The summer tests were conducted in the following order: schedules 4, 2, 3 and 1, thus leaving the adjoining anchors of schedule 1 in place for the winter measurements. For each test schedule, the same anchorage was also provided in 10 panels of track each side of the dynamic test panel. Obviously, the anchors in the 20 track panels, and not those in the test panel, controlled the movement of the rails.

Although precise measurement of the rail movement was made by two methods, the variables of train length, class and sequence of the traffic, rail position with respect to the easterly or westerly limits, and rail temperature during the summer schedules, made it difficult to compare the dynamic rail movements, except by using comparable groups of trains. Because of the many variables, the movement for 100 cars was analyzed in 2 ways. This information is shown in Table 2. In addition, a comparison of the range of rail movement for the five test schedules is also included in the table. In Parts A and B of Table 2, schedule 1 (summer) had the smallest rail movement per 100 cars, and schedule 4 was highest. Schedule 2 was the second lowest and schedule 3 was the third lowest. Because the trains were running off schedule and sequence during the winter measurements, no good comparison could be made. However, generally, the rail movement per car in the winter test was approximately 50 percent more than in summer schedule 1. The rail moved more freely in the winter with internal strains in tension. It was also observed that closing and opening of some of the rail gaps occurred, and this contributed to the larger rail movement under trains during the winter. Part C, Table 2, gives a comparison of the average maximum range of movement of the two rails. Schedules 1 through 4 ranked in the same order as in Parts A and B. Schedule 1–W (winter) was a little less than in summer schedule 1. This was no doubt influenced by having the ties partially frozen in the ballast.

Schedules 2, 3 and 4 all had 4–4 anchors to the rail; and the differences in the effectiveness of the three arrangements of anchorage can be directly attributed to their spacing and whether they were boxed against the ties. Of those three plans of anchorage, the performance of the rail anchors in schedule 2, with the anchors boxed on both ends of four widely spaced ties in a track panel, was good, considering the number of anchors used. Schedule 4, "end-of-rail" method, was the least effective for minimizing rail creepage. Schedule 1, 8–8 anchors boxed on two groups of four alternately spaced ties per rail, was superior in limiting the range of rail movement in the summer.

Because of the presence of skewed ties in the 20 track panels for the 4 arrangements of anchors, it was not possible to set each anchor in good contact with the ties. If all of these anchors could have been set in contact with the ties, it is probable that the range of movement of the rails would have been less, particularly in schedule 1 with 8–8 anchors per rail boxed.

It should not be interpreted from this report that the anchorage in schedule 2 is adequate for controlling rail creepage. Schedule 2 was similar to method F of the service tests which was in Mile 23 during the 4-year service period. Method F, with four widely spaced boxed ties per track panel, was also used in other locations during a part of the test period. After four years' service, method F anchorage in Mile 23 had churned the anchored ties in ½ of the test mile, which had a pronounced summit at the middle of the mile. In Mile 18, with a shallow sag in the track profile, method F–2, which had 6 ties boxed on both ends per panel, was unsatisfactory because of the anchored ties being churned in the ballast. Good anchorage must control rail creepage during the four seasons of a year in which rail movement is subject to the effect of a large range in temperature, possibly as much as 150 deg F.

PART 2. STATIC RESISTANCE OF TIES TO MOVEMENT IN GRAVEL BALLAST

GENERAL

Foreword

After completion of the dynamic test schedules during the summer, the same track devices and electronic equipment were used in other track panels for the purpose of determining the resistance of the ties to movement in the gravel ballast by breaking the track at both ends of the test panels and jacking each rail for three methods of anchorage. As far as can be ascertained, this test was the first one ever to be made by moving several ties at once and measuring accurately the force carried by each anchor to develop information on the tie resistance with respect to position in two groups of anchored ties. The ballast was pit run gravel of various sizes of stones up to 3 in, and contained 40 percent, or more, of sand. The track had not had a general surfacing for about six years.

Static Test Schedules

Tests were made with three arrangements of anchorage as follows: Schedule 5, similar to dynamic schedule 1, involved moving two groups of four alternately spaced ties in a panel of track; schedule 6 had two groups of four consecutive ties centered about the quarter-panel points; and schedule 7, similar to schedule 4 ("end-of-rail" anchorage), involved the movement of one end of two groups of four consecutive ties located near a joint in each rail. Schedules 5 and 6 were included in order to determine the difference in the resistance of the ties to movement in the ballast when alternately and consecutively spaced. Schedule 7 was investigated to develop information on the tie resistance to moving one end and skewing it in the ballast. Schedule 7 was conducted in a track panel east of the dynamic test panel and schedules 5 and 6 were located in separate panels west of the dynamic test panel.

Preparation for Static Test Schedules

All of the track devices, except the tie movement deflectometer, were installed in each test panel in a manner similar to that used in the dynamic tests, except that only the forward weigh bars were attached to the ties to be moved in the ballast. The Ames dials were mounted on short steel rods driven in the ballast for the purpose of progressively jacking the two rails the same distance to avoid skewing the anchored ties being moved by both rails.

In order to facilitate closing up the track for a train quickly, a 39-ft rail was removed from each side of the track and replaced with one each of 36-ft 3½-in, 26-in, and 6½-in lengths. The 6½-in dutchman was held in place by using 6-hole joint bars instead of the existing 4-hole bars. Another 4-hole joint was placed on the 26-in rail. The 26-in length provided room for the 25-ton hydraulic journal jack, load cell and blocking, and the 6½-in gap provided clearance for moving the rail forward. To avoid slipping of the jack or load cell, Fabreeka pads were used against the rail ends, jacks and load cells. A view of the arrangement for jacking the rails and measurement of the load is shown in Fig. 8.

Because greater forces on the weigh bars and larger movements of the rails were anticipated, the strain gage channel sensitivity for each was reduced below that used in the dynamic tests.

The load cells used (Fig. 8) were designed by the AAR research staff under the direction of R. Ferguson, electrical engineer. The cells were made of nickle–chromium steel, SAE 3145, and quenched and drawn to a Brinell hardness of 300. The cells are 2½ in diameter by 4 in long, with the center portion having a 1-in diameter for stress measurement. Two SR–4, ½-in rosette wire resistance strain gages were mounted on a diameter at the mid-length of the cell. The longitudinal components of the rosettes constituted the working gages, and the transverse components served as balancing gages in the strain gage circuit. Each cell was encased with circular brass plates to provide protection for the strain gages and wiring.

A laboratory calibration of each cell was made in a compression–tension testing machine for determining the relation between the applied load and the measured stresses in the 1-in diameter portion. The calibration extended to a maximum load of 75,000 lb without developing permanent set in the cells. Because the balancing strain gages were subjected to the Poisson effect of the primary compressive stress in the strut of the load cell, the measured stresses included the Poisson stress. The load conversion factor for each cell was constant, and the Poisson stress (tension) was 24 percent of the direct compressive stress.

All of the rail anchors were removed from the rails which were to be jacked, except those having the thrust bolts for engaging the weigh bars.

DISCUSSION OF TEST DATA

Oscillograms

An oscillograph recording was taken for each rail during the jacking period. Because the oscillograms were simple and easy to interpret, no specimen will be presented. For each pull on the jacking lever, the rail deflectometer traces had an offset in the trace which leveled off parellel to the base line. Because of the characteristics of the hydraulic journal jacks, after each loading movement of the jacking lever the load dropped slightly from the maximum reached for each step in the trace. This pattern was also reflected in the traces for the forces on the weigh bars to a lesser extent, but was not apparent on the trace for the rail movement. Simultaneous values of the jacking load and weigh bar forces were read from the records for the maximum values for each step in the traces.

Static Forces vs. Rail Movement

A resumé of the measured static forces applied to each weigh bar in both rails for a rail movement up to 0.30 in is presented for the three schedules in Figs. 9, 10 and 11. In addition, the jacking load required for the rails in each side of the track is shown in the graphs. The number of rails that were moved longitudinally is shown for each curve. Later, the jacking loads will be analyzed for determining the average restraint from friction and binding of the rail against the tie plate shoulders. A location plan of the test panels with the anchored tie numbers is shown in the upper right portion of each figure. The legend for the curves by tie position in each group of anchored ties is shown in the upper left portion of each figure. The front tie in each group is the one farthest from the jacks. Generally, the front ties would be expected to have the greater resistance to movement in the ballast after the curves assume a decreasing slope. Because of the many variables in track and ballast, there were several exceptions to this natural characteristic for some of the weigh bars.

In Fig. 9, schedule 5, for moving in the ballast two groups of four alternately spaced ties, the curves for the weigh-bar forces were relatively straight and closely grouped up to 0.15-in rail movement in the north rail and to a lesser extent for the south rail. At 0.30-in rail movement the forces on the weigh bars varied from approximately 1000 to 2500 lb. The mean curves indicate that the ballast started to yield at a rail movement of approximately 0.15 in. A number of the individual curves assumed a descending slope, and the forces for the maximum rail movement were smaller than those for a lesser rail movement. In this schedule only, the movement of the unanchored ties of the test panel was checked after jacking the rails 1 in. The movements ranged from ⅞ in for tie 4 near the jacks to $\frac{1}{16}$ in for tie 21 near the opposite end of the test panel. It was also observed elsewhere along the rails being jacked that an occasional unanchored tie had been moved in the ballast. This explains why the required jacking load was of such large magnitude.

Schedule 6, Fig. 10, for moving two groups of four consecutively spaced ties, had a widely different pattern in the weigh-bar forces as compared with schedule 5. The values had more scatter than in schedule 5, and the ballast started yielding with less rail movement. At 0.30-in rail movement, the range of forces was from about 200 to 3100 lb, compared with 1000 to 2500 lb for schedule 5. With the ties alternately spaced in schedule 5, the uniformity of the tie resistance to movement was superior to that of the consecutively spaced ties in schedule 6. This greater uniformity of resistance should cause less disturbance in the ballast. The mean curves for schedule 6 show little increase in resistance beyond about 0.20-in rail movement.

In Fig. 11, schedule 7, the front tie in each group of four consecutive ties anchored on only one end had the largest forces after a rail movement of about ⅛ in. The scatter of the forces at 0.30-in rail movement for the other three tie positions was the smallest in this schedule. The lowest individual curves in schedule 7 were well above several curves in schedule 6. The mean curves had a gradual decreasing slope from a point close to the origin, but had not leveled off at 0.30-in rail movement, as in schedule 6.

Fig. 12 is included to give a comparison of the tie resistances for the three schedules by position in the groups of ties moved in the ballast. In all schedules the front-position ties resisted the larger forces, and schedule 5 had the forces more nearly equalized for the four positions. Curves for the second-position ties were the next highest in all three schedules. The rear ties were the third highest, and the third-position ties, the lowest in each schedule. The mean curve is the lowest in schedule 6 and highest in schedule 7, in which the ties were skewed in the ballast. The characteristic leveling off of the mean curve in schedule 6 is in evidence.

A summary of the average resistance of the ties per anchor to movement in the ballast for the three schedules is given in Fig. 13 and Table 3. Values for schedule 7 were the largest for all increments of rail movement, but those for schedule 5 were only slightly less. For the larger rail movements the curve for schedule 6 was well below the curves for the other schedules. For rail movement of ⅛ in or more, the excess resistance of the ties in schedule 7 over that for schedule 5 was very moderate considering that in schedule 7 the ties were also being skewed in the ballast.

At ⅛-in rail and tie movement, the resistance of the ties per anchor was 1180, 1010 and 1280 lb, respectively, for schedules 5, 6 and 7. The uniformity of the individual values at ⅛-in rail movement was the best in schedule 5, ranging from 800 to 1460 lb. Schedule 7 was the next best with a range from 620 to 1660 lb. Schedule 6 was the poorest, with a range from 220 to 2160 lb. Likewise at $\frac{3}{16}$-in tie movement, the uniformity of the forces in the ballast was best in schedule 5 and the poorest in schedule 6. By having a greater uniformity of rail creepage forces acting in the ballast, as in schedule 5, there should be less disruption of the ballast in the cribs and less expense in retamping the ties. For all practical purposes, the holding power of the gravel ballast when not frozen should be considered not to exceed 1200 lb per anchor for rail movement not exceeding ⅛ in. Schedule 7 had somewhat the highest resistance values per anchor, but the ties in the original service tests were skewed in the ballast in some locations, which spoiled the line and gage of the track as well as the tamping. In one of the service tests it was necessary to surface out-of-face 3 miles of track to correct the track conditions for high-speed operations where this method of anchorage had been in use.

Binding and Frictional Forces Per Tie Plate

In Figs. 9, 10 and 11, curves were included to show the total jacking loads required to move the rails in the static tests. From simultaneous values of the jacking load for each rail and the summation of the forces exerted on the anchored ties being moved in the ballast, the jacking load required to move the number of rails indicated in the figures was determined. These values were then converted to the average force exerted on the unanchored ties per tie plate. These data are represented by the curves shown in Fig. 14. The rails were jacked to the west for schedules 5 and 6, which were conducted in panels west of the dynamic test panel. Schedule 7 was conducted in a panel east of the dynamic panel by jacking the rails eastward. The tests were conducted in the following order: Schedule 6 with consecutive anchored ties, schedule 7 with consecutive ties anchored on one end, and schedule 5 with the anchored ties alternately spaced. In the first test, schedule 6, the trace for the south rail jacking force went off the record at 0.09-in rail movement because of the large binding force on some of the unanchored ties. The spikes were lifted in four ties to avoid disrupting the ballast.

The curves include friction between the tie plate and rail which is estimated at 15 lb per tie plate, which is small in relation to the binding force caused by the skewed ties. For schedule 5 and the north rail of schedule 6, the binding forces reached maximum values from 280 to 415 lb per tie plate, while those for schedule 7 were between 550 and 600 lb. These forces were highest in the latter schedule because the eight ties being moved on one end were being skewed in the ballast. This increased the binding force on the unanchored end of these ties.

After moving the rail 1 in. in schedule 5, the relative movement between the rails and unanchored ties was observed. It was found that the unanchored ties had moved in the ballast from ⅞ in near the jack to $\frac{1}{16}$ in at the other end of the test panel.

It is not known that these high binding resistances of the unanchored ties are effective in resisting rail creepage. However, in the service tests conducted prior to this investigation, it was observed that unanchored ties had been moved in the ballast by a ratchet action. It is known now that the ratchet action was due to the progressive rail creepage increment for each car of trains operating in one direction, but not the other. In those instances the binding force was apparently much greater in one direction than in the other. In the dynamic tests the rails moved freely over the range of rail movement which the conventional anchors established for each method of anchorage.

A record of the above mentioned ratchet action was obtained in schedule 3 when the tie deflectometer was accidently engaged with the north end of the wrong tie for the 7-car passenger train No. 25, WB, hauled by a 6-wheel truck diesel unit. The weigh bar on the tie was for eastward forces only, and there was no force transmitted to the tie in a westerly direction except that caused by friction and binding of the rail base. Both the tie and rail were moved in the ballast 0.05 in for this short train. It was skewed 4¼ in prior to the beginning of the dynamic tests. This explains why in the previous service tests in the same stretch of track in vicinity of Kansasville some of the unanchored ties had been moved very close to the anchored ties.

The magnitude of the friction and binding forces are considered abnormally large, and were the result of skewed ties causing the rail to bind between the tie plate shoulders and actually move some of the unanchored ties outside of the static test panels.

SUMMARY AND CONCLUSIONS

Dynamic Tests

These conclusions are based on Part 1 of this report covering the measurement of the forces exerted on the anchored ties and the movement of the rail and ties under two-way traffic.

1. The position of the primary maximum forward forces recorded on the weigh bars occurred ahead of each wheel before it reached the rail anchors which actuated the thrust bolts against the weigh bars. In cases where the rearward bars were engaged, those maximum forces occurred behind the wheels. These patterns of forces were satisfactorily correlated with the calculated angular variation of the rail depression curve, more commonly called the wave action of the rail. These angular changes swung the thrust bolts with a lever arm of 4⅜ in from the neutral axis of the rail and exerted forces on the weigh bars. Simultaneously with these forward forces, the rail creepage forces caused by rolling out the convex upward wave ahead of each wheel were present, but were masked out by those caused by the angular changes of the rail. Because of these phenomena, the dynamic forces (including the static loads on the weigh bars) proved to be unsuitable for judging the relative merits of the four methods of rail anchorage tested in schedules 1 to 4, incl.

2. It was determined that the magnitude of the total primary forward forces was greatly influenced by (1) existence of a static force on the weigh bar, (2) freedom of forward rail movement, (3) amounts of simultaneous backward rail movement and the accompanying backward tilt of tie at the wheels, and (4) the stability of the tie in the ballast bed. The greatest forces on the weigh bars occurred under the cars during the winter measurements when the ties were partially frozen in the ballast. The pattern of the magnitude of the dynamic forces during the winter measurements, except when the static forces were large, was in better agreement with the computed forces, because of the rigidity of the ties in the partially frozen ballast. Sudden movement of the rail in the summer measurements caused by changes in rail temperature or disturbing the track by a surfacing gang resulted in large forces, particularly under the locomotives.

No very large forces were measured under the braking and accelerating movements made by the way freight trains, although some of the maximum values for a schedule were recorded for these trains during the summer tests. If the trains had been braked to a full stop on the test panel, it is quite probable that the forces on the anchored ties would have been greater because large forces have been measured in the rail in connection with tests on bridges.

It was found that the magnitude of the dynamic forces was not a function of the train speed.

From an analysis of the rearward and forward forces exerted on the anchored ties by the thrust bolt anchors, it is evident that in the case of using two-way anchors in track they will subject the ties to the rearward forces as well as the forward forces. These rearward forces have no value as to restraining the normal rail creepage in the forward direction. It seems obvious to conclude that with the two-way anchor the average magnitude of the rearward forces will be appreciably less than the corresponding forward force value because the rail movement and tie tilt are in the wrong direction to aid in building up those forces. However, the accompanying reversals of force on the spikes that transmit the forces to the anchored ties will hasten the crushing of the wood and enlarge the spike holes.

3. It should be remembered that the rail deflectometers were used to measure the movement of the rail on level with the bottom of the base. The apparent forward and rearward movement of the rail for each wheel was the result of the 3-in lever arm (from the neutral axis of the rail) acting through the angular changes of the rail depression curve. Generally, in the summer measurements, there was no progressive forward movement of the rail under the locomotives. However, in a few instances the rail moved backward, ahead and under the locomotives, and occasionally there was a slight forward movement. In all cases the apparent forward and backward rail movement for each wheel was discernible from the records. Under a long freight train, the progressive forward rail movement under the first few cars was at a more rapid rate than for the succeeding cars. Under the rear portion of those trains, the movement leveled off, except for the back and forth movement for each car truck. Likewise, the pattern of the weigh-bar forces was uniform for the last few cars. The largest rail movement for a long train occurred with a reversal of traffic. Movement per car decreased with succeeding trains operating in the same direction because of approaching or reaching the limit of the rail movement established by the conventional anchors each side of the test panel.

The movement of the rail caused by an accelerating train showed the result of additional tractive effort at low speed. An analysis of the record revealed that the rail moved backward ahead of the locomotive. Immediately after this movement, which on occasion became quite large, there was the usual back-and-forth rail movement under the locomotive, followed by a moderate progressive forward movement of the rail under the cars. In comparing records of accelerating versus constant-speed runs with trains of comparable length the movement per car was slightly less in the accelerating than it was in the constant-speed runs.

In the event of a brake application, the rail moved forward in front of the locomotive. There was a tendency for the movement to be forward again directly underneath the locomotive, a condition which was not apparent in constant-speed runs. The results of a summary involving a number of braking runs and constant-speed runs indicated that, with comparable conditions, the braking runs showed more movement per car than in the constant-speed runs.

During the winter measurements, a very unusual rail movement occurred under a few long freight trains. For these runs, the dial readings indicated that the rail had reached its limiting forward position as fixed by the anchored ties outside of the test panel. Under the rear portion of these trains, the rail moved progressively backward and forward for several car lengths. The rail was very tight in the forward direction and this, together with the tensile stress in the rail set up by the temperature differential from summer to winter, caused the rail to move backward under these trains. The rearward rail movement was small, ranging up to 0.02 in, which was insufficient to engage the rearward weigh bars and produce rearward forces. The forward progressive rail movements were accompanied by moderate forward dynamic forces on the weigh bars, which disappeared completely with the backward rail movements. In these runs the conventional anchors relieved the weigh bars of the large forward forces.

4. The rail movement per car and the total range of its movement for the four summer dynamic test schedules are the most pertinent information obtained for judging the effectiveness of the four arrangements of rail anchorage. In this respect, schedule 1 (Table 2) was best with the lowest values, and schedule 4, with the largest values, was least favorable.

5. The tie movement deflectometer measured the displacements of the north end of the tie at a level 1½ in below the top, and the record obtained included tilting as well as the progressive movement. In general, the tie movement record was similar to that of the rail for each truck, and for a train the total movement was the same as that for the rail. There was one outstanding difference between the two records, which was caused by the tilting of the ties in the ballast. Although the tilting movements were rather small, ranging up to 0.02 in, they had an important effect on the weigh-bar forces because 0.01 in deflection of the beam required 700 lb. When the anchored tie had little or no live load, it could be tilted or rocked forward with a moderate amount of static load ahead of the train. It is also possible for the dynamic forces to produce a small forward additional tie tilt ahead of the wheel and before the tie plate received much load between widely spaced wheels. As the wheels approach the tie, it tilts backward to a normal bearing. This movement will add some dynamic force to the forward weigh bar in some cases and always provide sufficient restraint to prevent full releases of the dynamic forces between cars and axles of a truck.

It has been demonstrated that a tie was moved in the ballast without being pushed by an anchor. This so-called ratchet action utilizes the friction and binding force between the rail and tie plate and tends to move the ties in only one direction, resulting in skewed unanchored ties. Sometimes unanchored ties were moved close to the next tie in the service tests of rail anchors in the track near Kansasville. It is judged that these events are more prevalent in ballast with lower values of holding power than in the types of ballast that provide the ties with greater resistance to movement.

6. It has been shown that a portion of the rail creepage force transmitted to the side of the tie by a rail anchor was a function of the angular changes of the rail depression curve and the length of lever arm from the neutral axis of the rail. Those types of rail anchors which extend farthest below the rail base and are rigidly fastened to the rail base with the longer lever arms, will exert larger forces and probably crush the ties more.

Static Tests

Although the average force per rail anchor to move a tie in gravel ballast in schedule 7 ("end-of-rail" method) was the greatest, it did not exceed the corresponding value in schedule 5 as much as would be expected. Considering the small difference in resistance to tie movement and the maintenance problems caused by skewed ties in schedule 7, schedule 5 with greater uniformity of the force distribution in the ballast is by far the best arrangement for track. Schedule 6 has the lowest average resistance per anchor for rail movements over ⅛ in. and the largest variation of the forces in the ballast. Anchoring alternate ties is the optimum for effective anchorages at overall minimum cost, except in special locations where more anchors are needed to control rail creepage. Efficient and economical utilization of the holding power of the ballast to control rail creepage cannot be achieved by bunching rail anchors beyond the capacity of the ballast in a portion of a panel of track, and failing to use the other portion.

From other static tests made in different types of ballast by others, it is judged that the gravel ballast tested provided a low holding power for the anchored ties.

From the information given on the magnitude of binding and friction forces on the unanchored ties, it is detrimental to track to use anchors in such a manner as to cause skewing of ties. Skewed anchored ties will tend to skew adjacent unanchored ties. The large binding forces, together with information from the dynamic tests, fully explain the ratchet action in track which has resulted in unanchored ties being moved in the ballast.

ACKNOWLEDGEMENT

The conduct of this test and preparation of the report were under the general direction of G. M. Magee, director of engineering research, AAR. The test was planned and the report was prepared by H. E. Durham, research engineer track, who was assisted by A. D. Van Sant, assistant research engineer track, and members of the track staff. The field stress measurements were conducted under the direct supervision of M. F. Smucker, assistant electrical engineer.

The Association gratefully acknowledges the fine cooperation and keen interest on the part of the Milwaukee Road, and also the P.&M. Co. which furnished the test anchors.

TABLE 1. COMPARISON OF THE THREE LARGEST VALUES OF TOTAL FORCE EXERTED ON THE RAIL ANCHOR WEIGH BARS UNDER LOCOMOTIVES AND CARS FOR EACH RAIL AND TEST SCHEDULE

Part 1. LOCOMOTIVES (See foot notes).																	
NORTH RAIL									SOUTH RAIL								
Run No.	Locomotive	Train	Direction	mph	Tie No.	Weigh Bar Force in lb Static	Dyn.	Total	Run No	Locomotive	Train	Direction	mph	Tie No.	Weigh Bar Force in lb Static	Dyn.	Total
SCHEDULE 1W - WINTER																	
North Rail Excluded in Winter Test									16-W	1-U(6)	Pass.	EB	68	21	180	510	690
									"	"	"	"	"	19	17[illegible]	460	630
									"	"	"	"	"	17	190	430	520
Average																	610
SCHEDULE 1																	
61	4-U(4)	T. Frt.	WB	33	7	660	1300	* 1960	52	2-8-2	X. Frt.	EB	27	5	260	850	1110
"	"	"	"	"	5	1050	800	1850	"	"	"	"	"	"	260	840	1100
"	"	"	"	"	"	1050	800	1850	"	"	"	"	"	"	260	830	1090
Average								1890									1100
SCHEDULE 2																	
18	4-U(4)	T. Frt.	EB	42	3	0	840	840	27	2-8-2	L. Frt. A	WB	16	19	0	430	430
23	4-U(4)	T. Frt.	EB	45	19	0	570	570	"	"	"	"	"	3	0	430	430
"	"	"	"	"	"	0	560	560	"	"	"	"	"	"	0	380	380
Average								590									410
SCHEDULE 3																	
45	4-U(4)	T. Frt.	WB	27	5	1560	470	2030	47	4-U(4)	T. Frt.	EB	20	19	410	1500	1910
"	"	"	"	"	"	1560	460	2020	"	"	"	"	"	"	410	1430	1840
"	"	"	"	"	"	1560	60	1620	"	"	"	"	"	"	410	1330	1740
Average								1890									1830
SCHEDULE 4																	
2	2-8-2	L. Frt.	EB	36	8	360	940	1300	11	4-U(4)	T. Frt.	EB	51	19	0	710	710
"	"	"	"	"	"	360	920	1280	"	"	"	"	"	"	0	680	680
"	"	"	"	"	"	360	870	1230	"	"	"	"	"	"	0	660	660
Average								1270									680
Part 2. PASSENGER OR FREIGHT CARS																	
SCHEDULE 1W - WINTER																	
North Rail Excluded in Winter Test									13-W	4-U(4)	X. Frt.	WB	47	3	2750	180	2530
SCHEDULE 1																	
65	2-8-2	L.Frt.A	WB	23	15	240	990	1230	65	2-8-2	L.Frt.A	WB	23	5	150	1250	1400
"	"	"	"	"	"	240	990	1230	57	2-8-2	L.Frt.B	EB	37	5	220	1150	1370
"	"	"	"	"	"	240	980	1220	"	"	"	"	"	"	210	1130	1340
Average								1230									1370
SCHEDULE 2																	
25	4-U(4)	T. Frt.	WB	42	15	270	1450	1720	27	2-8-2	L.Frt.A	WB	16	7	90	700	790
"	"	"	"	"	"	270	1390	1660	"	"	"	"	"	"	90	680	770
"	"	"	"	"	"	270	1360	1630	"	"	"	"	"	"	90	630	720
Average								1670									760
SCHEDULE 3																	
40	1-U(6)	Pass.	EB	68	7	330	1190	1520	48	2-8-2	L.Frt.B	EB	31	19	230	1370	1600
"	"	"	"	"	"	410	1090	1500	"	"	"	"	"	"	230	1330	1560
"	"	"	"	"	"	360	1130	1490	"	"	"	"	"	"	230	1300	1530
Average								1500									1560
SCHEDULE 4																	
14	2-8-2	L.Frt.A	WB	18	7	370	870	1240	11	4-U(4)	T. Frt.	EB	51	19	80	820	900
"	"	"	"	"	"	370	860	1230	2	2-8-2	L. Frt.	EB	36	19	190	630	820
"	"	"	"	"	"	370	850	1220	11	4-U(4)	T. Frt.	EB	51	19	20	750	770
Average								1230									830

Notes:
4-U(4) = Four 4-wheel truck diesel units. 1-U(6) = One 6-wheel truck diesel unit. 2-8-2 = Moderate weight Mikado steam locomotive. In the train columns: T = Time freight Nos. 75 or 86, L = Way freight Nos. 95 or 96, X = Extra train, A = Train accelerating, B = Train braking. Runs with the direction underlined were preceded by a train operating in the same direction. Speeds shown for trains braking or accelerating are for the locomotive at the test panel.

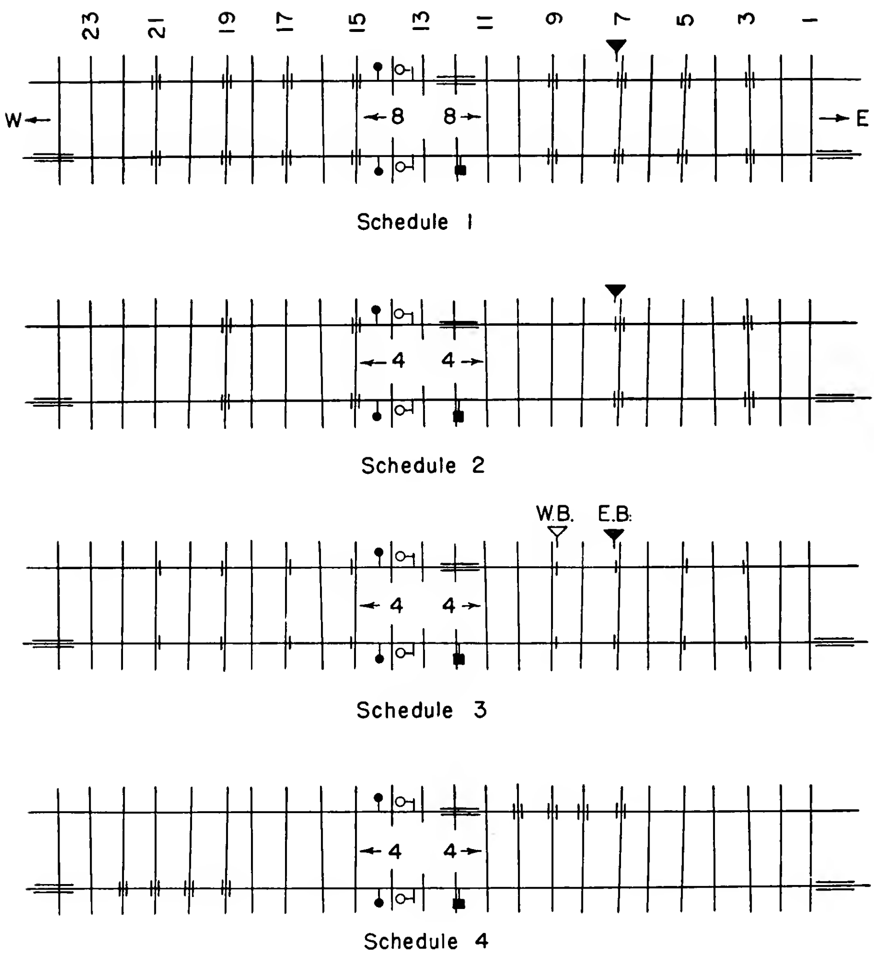
TABLE 2. COMPARISON OF RAIL CREEPAGE FOR FOUR METHODS OF RAIL ANCHORAGE ON THE MILWAUKEE ROAD NEAR KANSASVILLE, WIS.

Schedule No.	No. of Cars	Avg. Rail Temp. °F.	Avg. Movement of Both Rails: Total in.	Per 100 Cars in.	Relative Movement Percent
A. Rail movement determined from the oscillograms for four typical daily trains which operated in the following order: WB time freight, EB passenger, WB way freight and EB time freight.					
1	194	106	0.483	0.249	100
2	240	93	0.720	0.300	121
3	195	101	0.682	0.350	141
4	188	80	0.897	0.477	192
B. Rail movement from dial readings, including the effect of rail temperature changes, for 2 or 3 typical days in each schedule.					
1	571	104	1.496	0.262	100
2	500	90	1.596	0.319	122
3	647	93	2.184	0.338	129
4	699	90	2.730	0.391	149

In the above comparisons, a steam locomotive was equated to two cars and a diesel unit to one car. Schedule 1-W for the winter test was omitted because the daily trains did not operate in the same sequence as during the summer.

C. Maximum range of movement of both rails (including the effect of temperature changes) obtained from the dial readings. Range of rail movement is defined as the distance between its extreme easterly and westerly positions.

Schedule No.	No. of Days	Range of Rail Temp. °F.	Avg. Max. Range of Both Rails: in.	Relative Percent
1	4	124 - 72 = 52	0.347	100
2	3	113 - 76 = 37	0.424	122
3	4	118 - 67 = 51	0.546	157
4	4	128 - 74 = 54	0.591	170
1-W (winter)	6	49 - 25 = 24	0.321	93



- Rail anchor weigh bars recording forces on the ties.
- Rail deflectometers for recording longitudinal movement.
- Ames dials for measuring rail movement.
- Wheel position marker.
- Deflectometers for measuring tie movement.

Fig. 1. Four Arrangements of Rail Anchor Weigh Bars for Measurement of the Forces Exerted on the Ties Under Traffic in Both Directions.

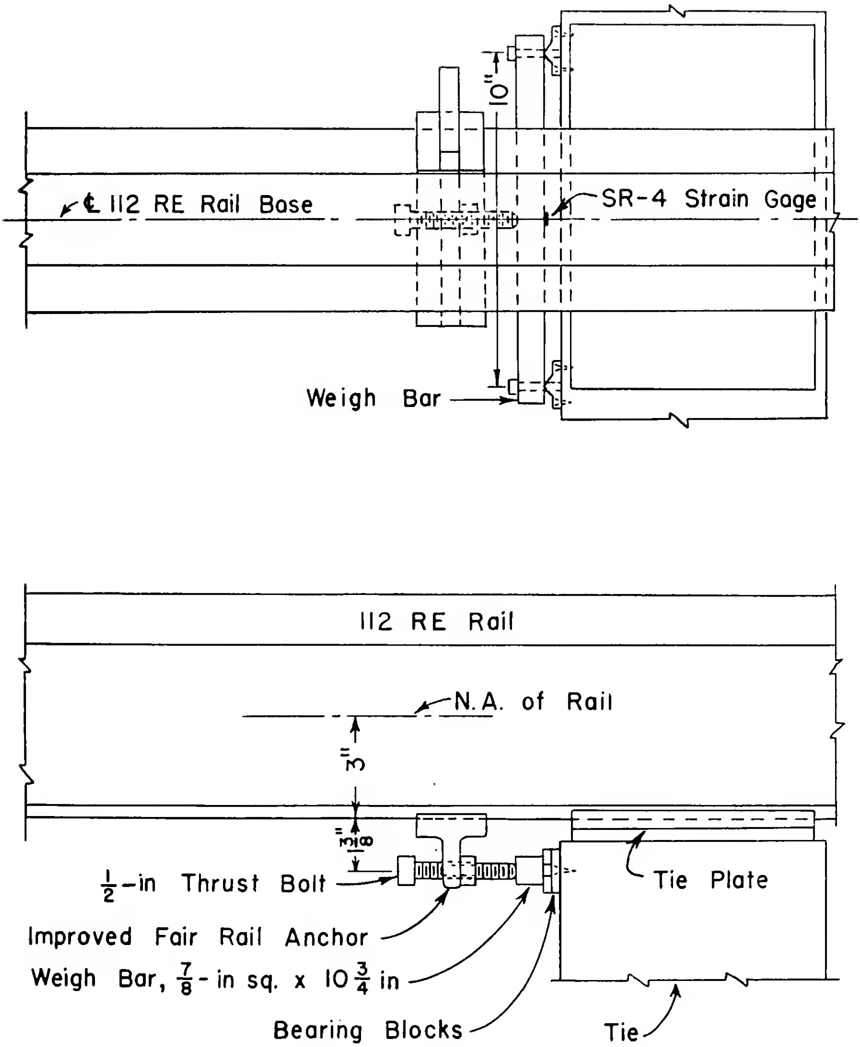


Fig. 2. Plan of Weigh Bar for Measuring Rail Creepage Forces

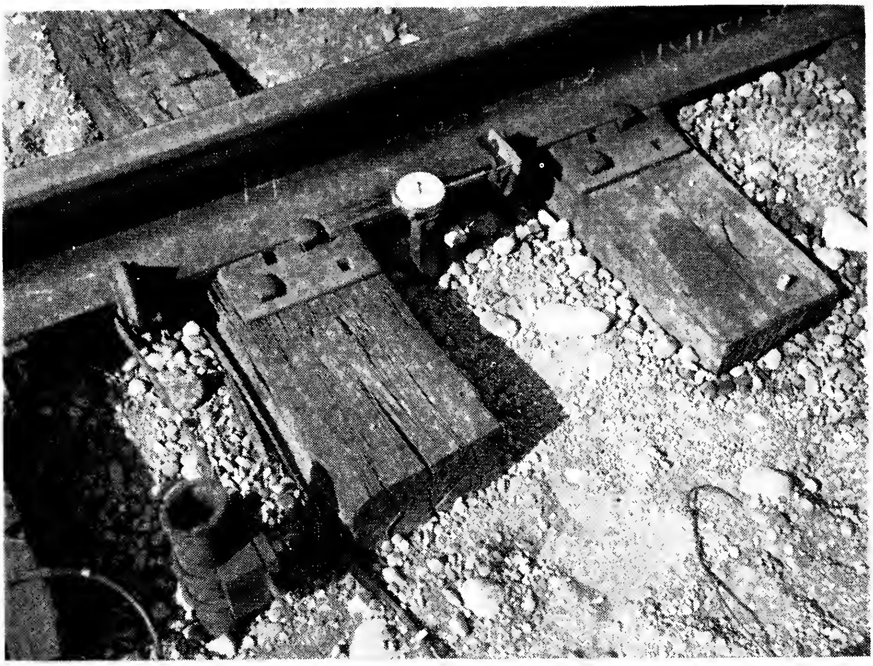


Fig. 3. Deflectometer and Ames Dial Indicator for Measurement of Longitudinal Rail Movement

Fig 4. Deflectometer for Measurement of Tie Movement in the Ballast

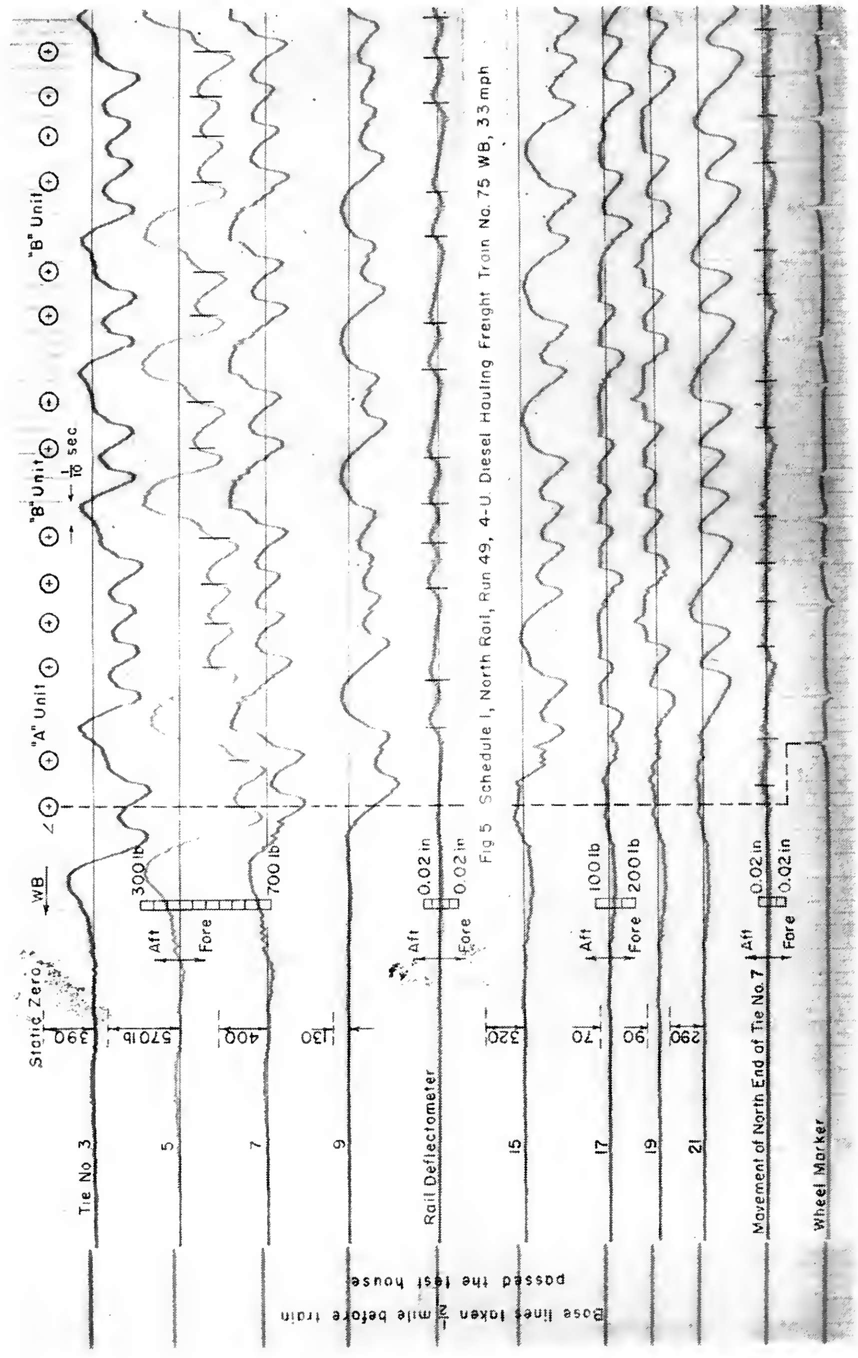


Fig 5 Schedule I, North Rail, Run 49, 4-U Diesel Hauling Freight Train No. 75 WB, 33 mph

A

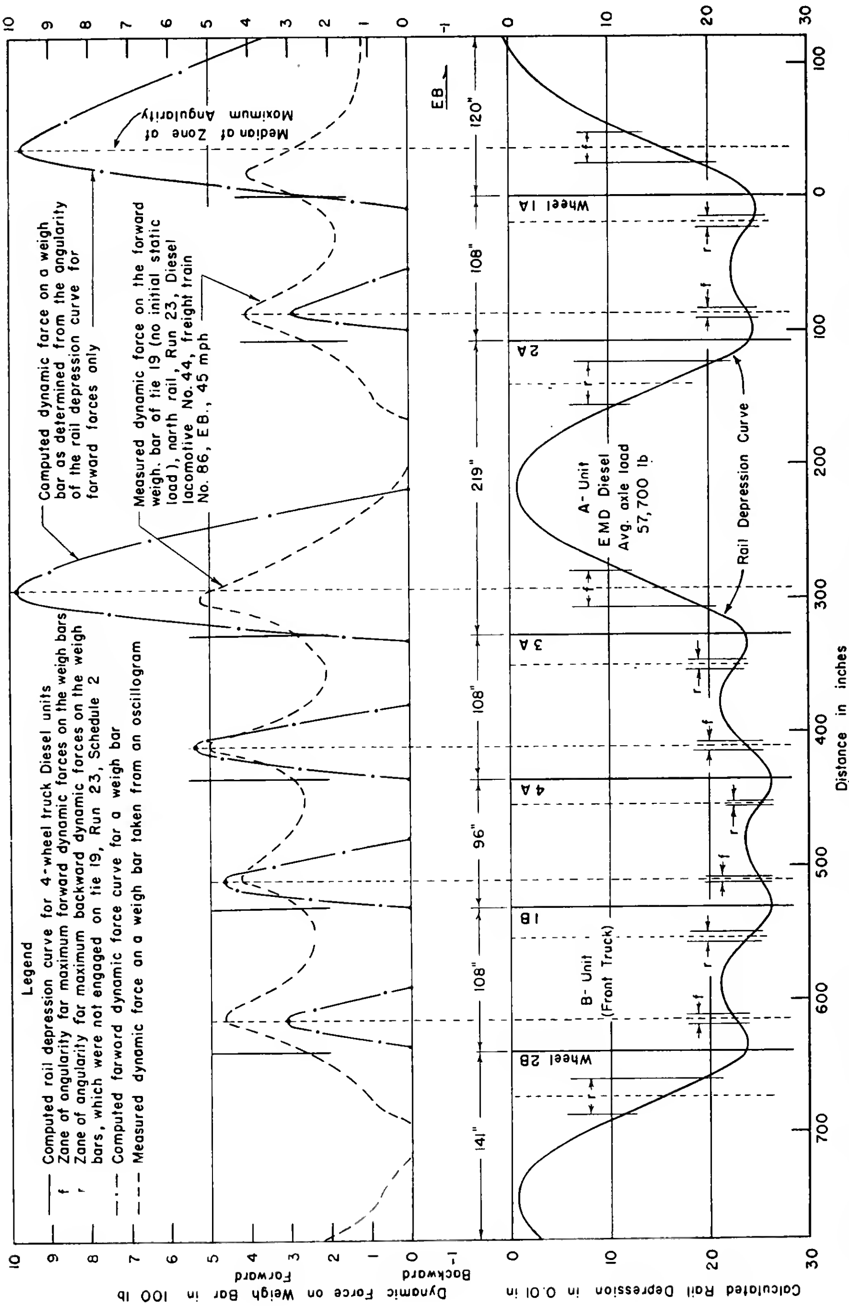


Fig 6 Correlation of the Measured Dynamic Forces on the Weigh Bars with Those Calculated from the Angularity of the Rail Depression Curve

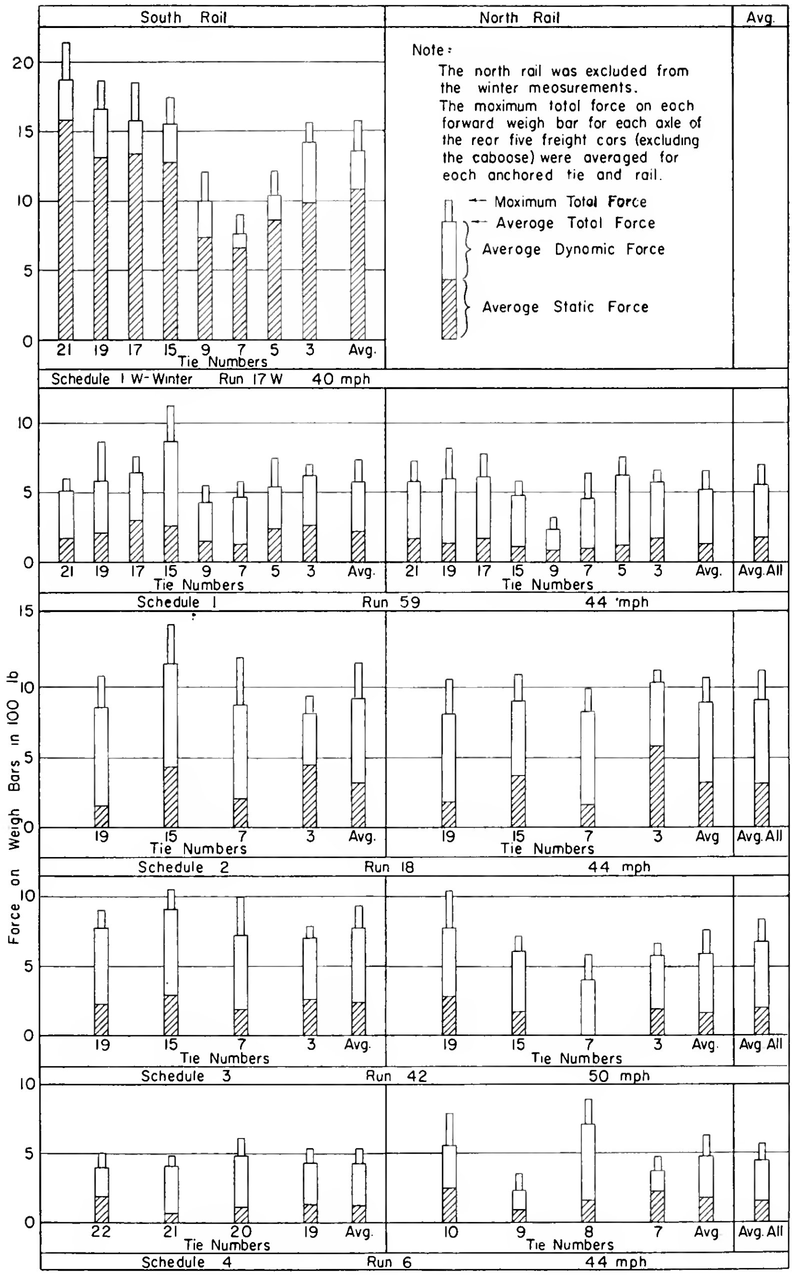


Fig. 7 Comparison of the Mean Measured Forces on the Weigh Bars in All Test Schedules for the Rear Five Freight Cars in Train No. 86, E.B., (Preceded by a W.B. Train)

Fig. 8. Set-Up for Jacking Each Rail and Measuring the Load Applied

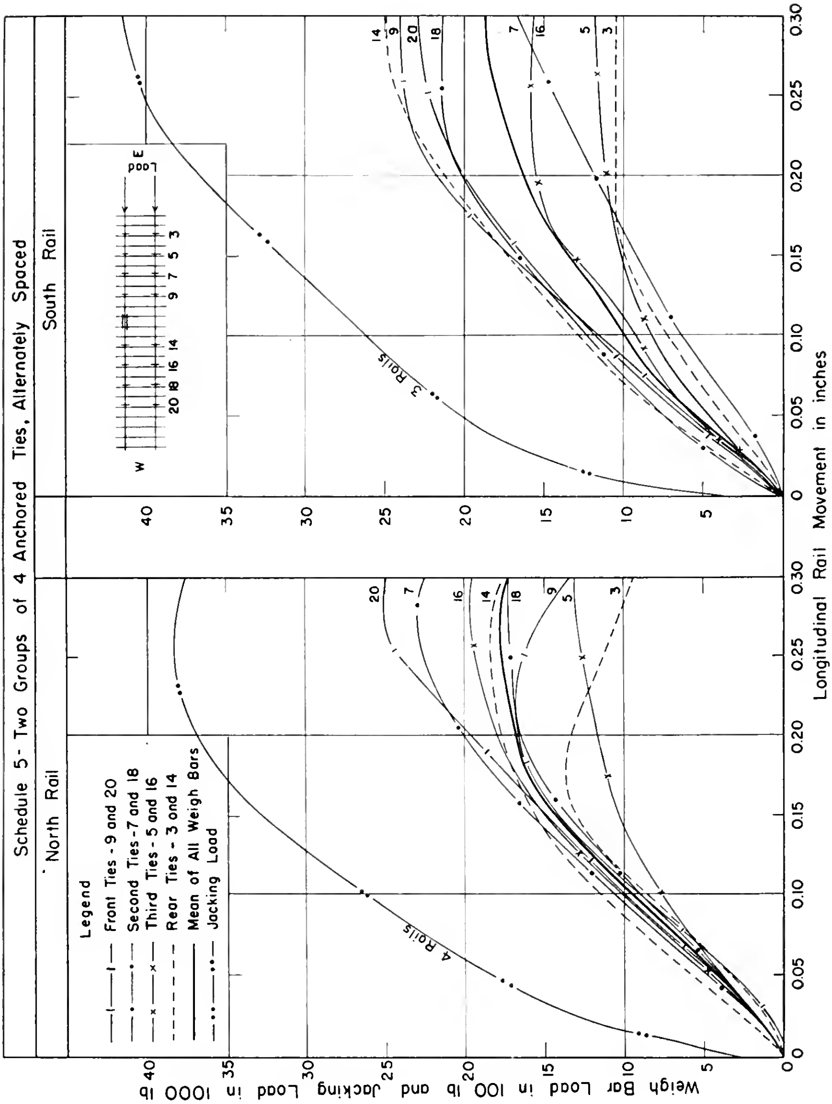


Fig. 9. Schedule 5, Resistance of Ties to Movement in Ballast

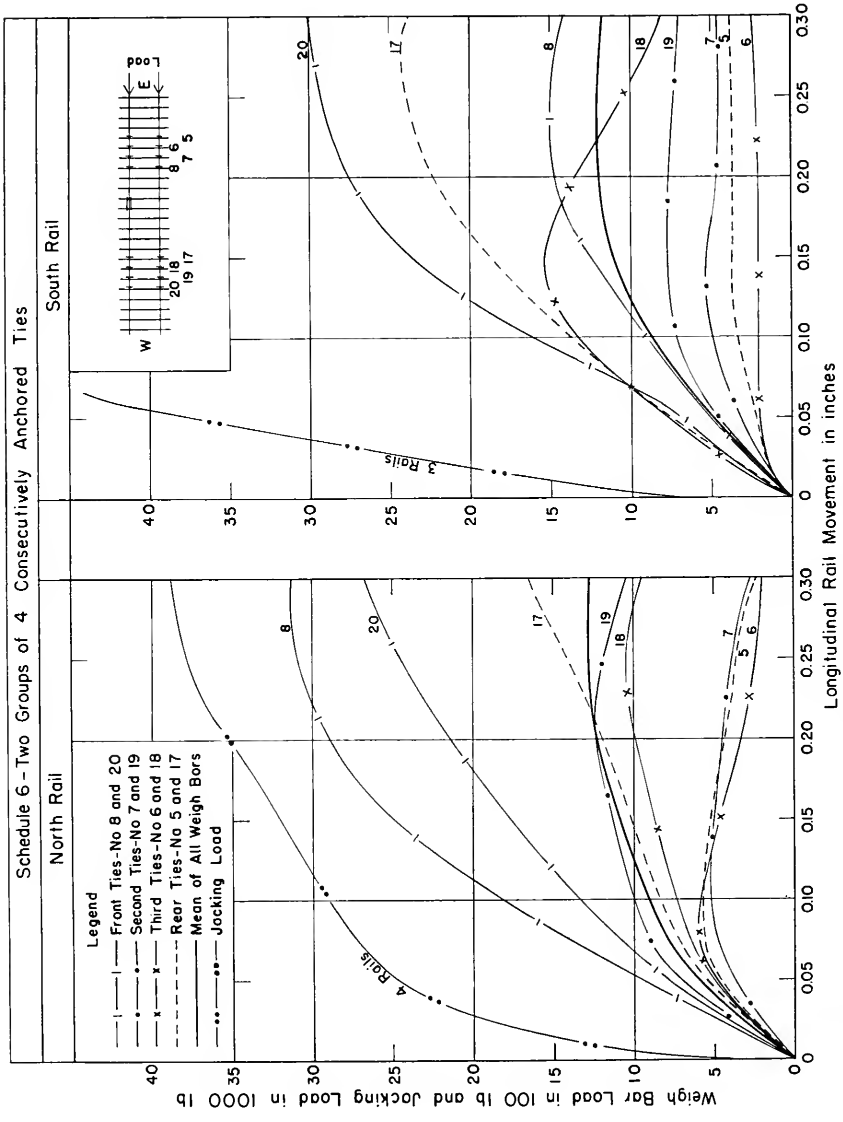


Fig. 10. Schedule 6, Resistance of Ties to Movement in Ballast

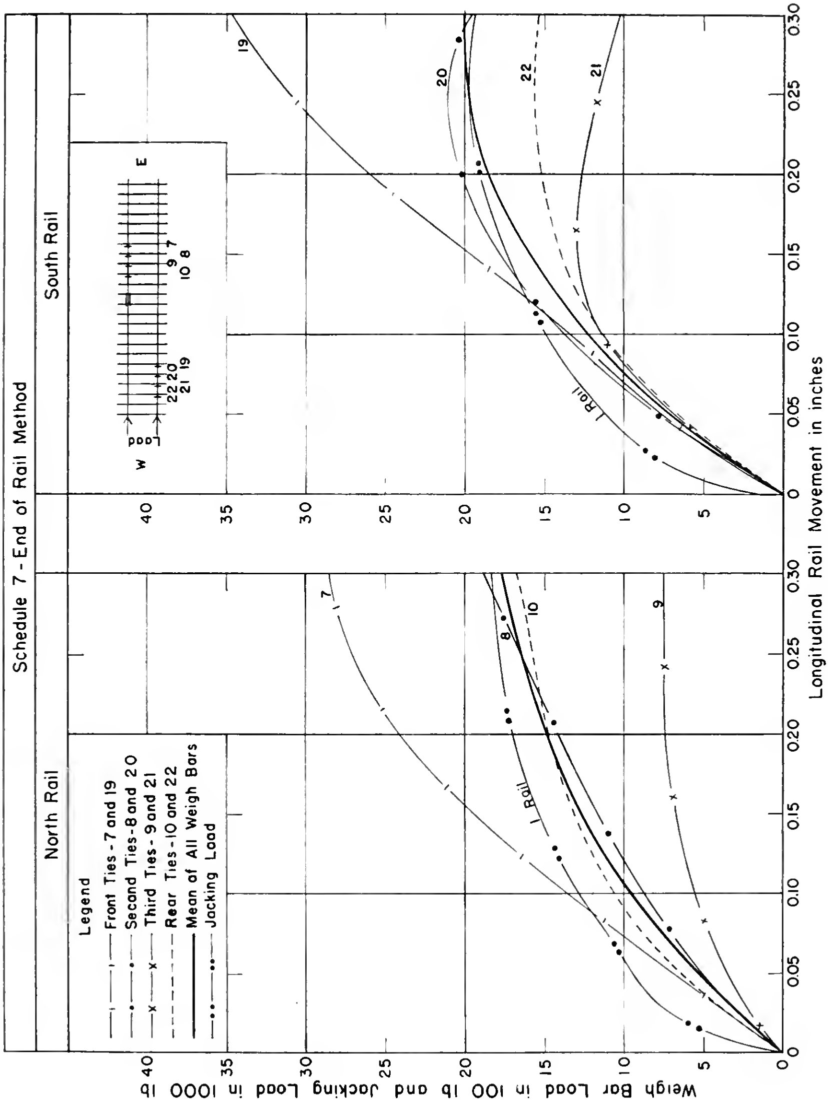
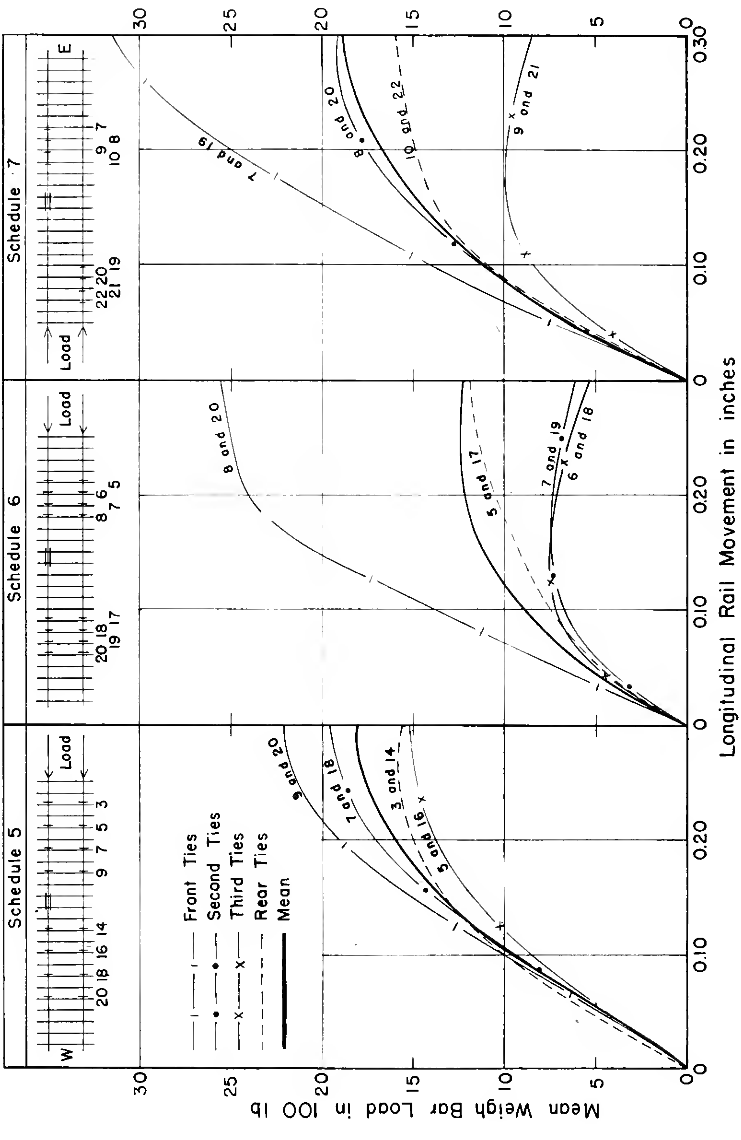


Fig. 11 Schedule 7, Resistance of Ties to Movement in Ballast



Note: Each curve for Schedules 5 and 6 is the average of four weigh bars on two ties, and for Schedule 7, each curve is the average of two weigh bars on one end of each of two ties.

Fig.12. Comparison of the Mean Weigh Bar Loads by Tie Position for Schedules 5, 6 and 7

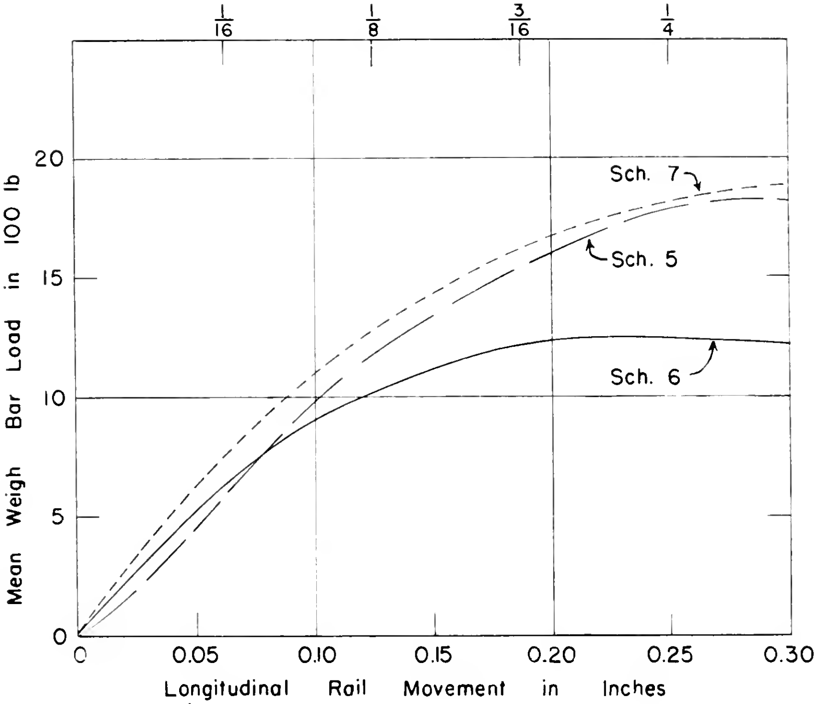


Fig. 13. Comparison of the Mean Weigh Bar Loads for Schedules 5, 6 and 7.

Rail Movement inches	Average Load on Weigh Bars in lb.		
	Schedule 5	Schedule 6	Schedule 7
1/16	600	640	770
1/8	1180	1010	1280
3/16	1540	1220	1630
1/4	1770	1250	1820
5/16	1810	1210	1890

Table 3. Summary of Resistance of Ties to Movement in Ballast for Schedules 5, 6 and 7.

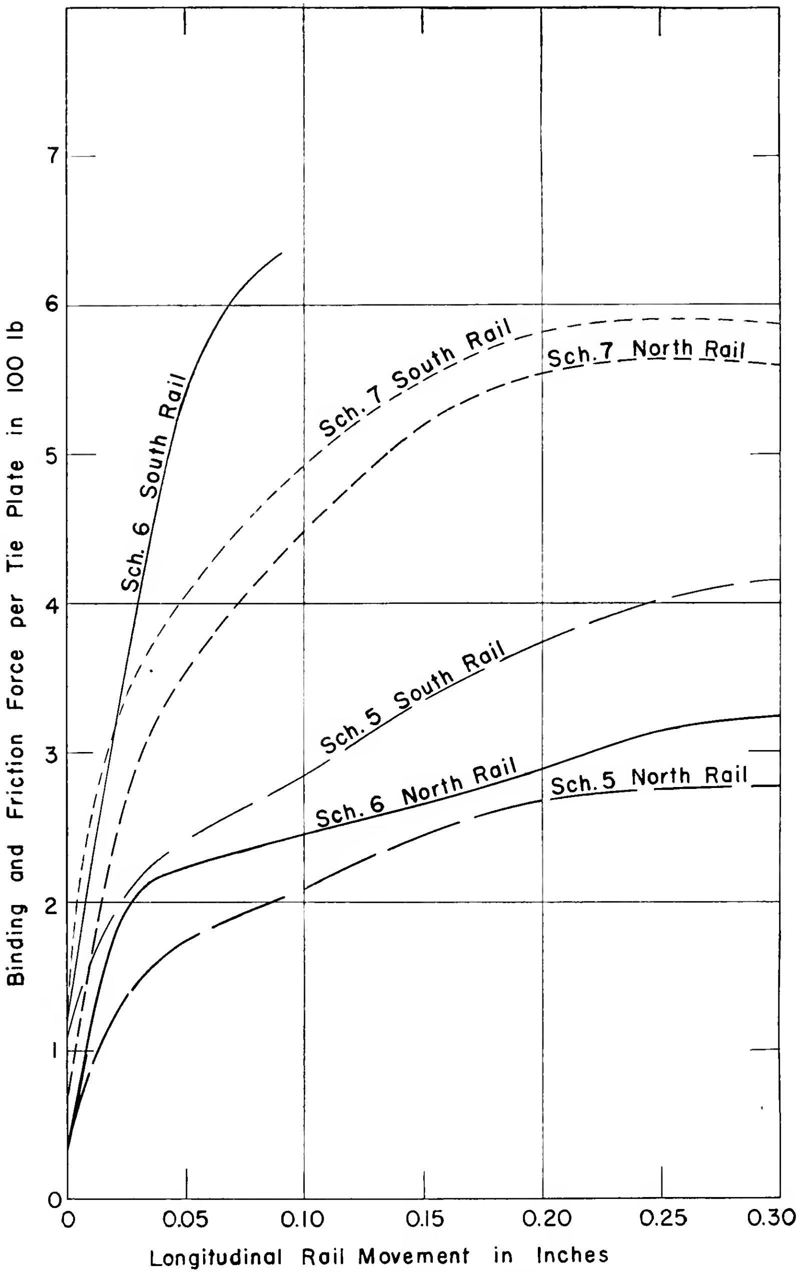


Fig. 14. Comparison of Binding and Friction Forces per Tie Plate on Unanchored Ties for Schedules 5, 6 and 7.

Report of Committee 16—Economics of Railway Location and Operation

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To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions .... page 324

2. Economics of retarder-equipped yards for classification switching, collaborating with Committee 14, Signal Section, AAR, and American Association of Railroad Superintendents.

   Final report, submitted as information .... page 328

3. Cause and effect of derailments and dragging equipment, collaborating with Committees 3 and 5.

   Final report, submitted as information .... page 332

4. Economics of "highway trailers on flat cars" service, collaborating with American Association of Railroad Superintendents.

   Progress report, submitted as information .... page 334

5. Comparison of running time with total time between loading and unloading points of freight cars, and methods of reducing total time, collaborating with Car Service Division, AAR, Signal Section, AAR, Communications Section, AAR, and American Association of Railroad Superintendents.

   No report.

6. Economics of improved freight stations and facilities, collaborating with Committees 6 and 14, and with Freight Station Section, AAR.

   No report.

The Committee on Economics of Railway Location and Operation
H. B. Christianson, Jr., *Chairman.*

AREA Bulletin 518, November 1954.

Report on Assignment 1

Revision of Manual

A. L. Sams (chairman, subcommittee), H. A. Aalberg, J. W. Barriger, C. H. Blackman, R. J. D. Kelly, H. P. Morgan, F. B. Peter, J. P. Ray, J. E. Teal.

On March 10, 1952, the Board Committee on Outline of Work, with the approval of the Board of Direction, asked Committee 16 to review all the material in the former Manual chapter on Complete Roadway and Track Structure, looking to bringing that material up to date, as might be necessary, for inclusion in Chapter 16 in the Manual as to be reprinted in 1953.

As a result of this review, Committee 16 recommended (see Proceedings, Vol. 54, 1953, pages 419 and 1295) that one of the documents in the chapter, entitled "Schedule of Classes of Complete Roadway and Track Structure", be withdrawn from the Manual because it made reference to a schedule, presented in detail in the Proceedings, Vol. 41, 1940, pages 640–645, which with respect to the items and page numbers given, would become entirely out of date after the Manual had been reprinted, with its new page numbers. The committee also recommended that this material be restored when the schedule in question could be brought up to date.

Accordingly, your committee submits herewith a new Schedule of Classes of Complete Roadway and Track Structure under AREA Recommended Practice as of 1954, in conformity with the Traffic Classification of Railway Main Tracks as presented in Chapter 16, Part 4 of the new Manual.

The three classes of complete roadway and track structure must not be regarded as definitely fixed and mutually exclusive as to details. For example, although 140, 133 and 132 RE rail sections are indicated only for Class A roadway and track structure, it is quite possible that under some conditions they may be economical for Class B roadway and track structure. Similarly, 90 RA–A rail under some conditions may be economical for Class A as well as for Class B and Class C roadway and track structure.

More unfavorable conditions than average, such as steep gradients, sharp curvature, tunnels and others which are not referred to in the Traffic Classification of Railway Main Tracks, may make economical, in whole or in part, a higher class of roadway and track structure than that indicated by annual tonnage and train speeds alone. Similarly, more favorable conditions than average may make economical, in whole or in part, a lower class of roadway and track structure than that indicated by annual tonnage and train speeds alone. Such unfavorable and favorable conditions, however, should be treated as special cases, and the track and roadway structure should be provided according to the specific requirements.

Having in mind the many variations in local conditions other than annual tonnage and train speeds, it is suggested that the several Schedules of Classes of Complete Roadway and Track Structure should be regarded either as applicable to average conditions, or as indicative rather than absolute insofar as their respective details are concerned.

When materials other than those noted are used they should be at least the equivalent of those noted, except that in the lower ranges of Class C main track the equivalent of 90 RA–A track is not required, and available materials may be used in accordance with actual requirements.

Your committee recommends that this report be accepted as information, and that immediately following the Traffic Classification of Railway Main Tracks as printed in Chapter 16, Part 4 of the Manual, there be printed a reference to this report, as set forth at the top of page 328.

Schedule of Classes of Complete Roadway and Track Structure Under AREA Recommended Practice 1954

Item	*Class "A"*	*Class "B"*	*Class "C"*	*Page in Manual*
ROADWAY				
General	Specifications	Specifications	Specifications	1–1–8
Width at Subgrade	As required	As required	As required	1–1–1 to 1–1–4
Slopes	As required	As required	As required	1–1–4 to 1–1–6
Slope Protection	As required	As required	As required	1–1–23 to 1–1–35
Surface Drainage	As required	As required	As required	1–1–45
Sub-surface Drainage	As required	As required	As required	1–1–46
BALLAST				
Sub ballast				
Material	As available	As available	As available	1–2–1
Ballast or Top Ballast				
Material				
Stone	Specifications	Specifications	Specifications	1–2–2
Slag	Specifications	Specifications	Specifications	1–2–2
Prepared Gravel				
More than 20% crushed	Specifications	Specifications	Specifications	1–2–2
20% and less crushed	Specifications	Specifications	Specifications	
Pit Run Gravel	See Note "A"	Specifications	Specifications	1–2–5
Cinders	See Note "A"	See Note "A"	As available	
Ballast Section				
With Sub-ballast	As required	As required	As required	1–2–6 to 1–2–12
Without Sub-ballast	As required	As required	As required	1–2–6 to 1–2–12
CROSS TIES				
General	Specifications	Specifications	Specifications	3–1–1
Kind	Best available	Best available	Best available	
Size	Ties 7 in thick	Ties 7 in thick	Ties 6 in thick	3–1–2, 3–1–6
Length	8 ft, 8 ft 6 in, or 9 ft	8 ft, 8 ft 6 in, or 9 ft	8 ft, 8 ft 6 in, or 9 ft	3–1–2, 3–1–6
Number per 39-ft rail	As required	As required	As required	
Treated	As required	As required	As required	
Adzed and Bored	Adze and Bore	Adze and Bore	Adze and Bore	3–1–7, 3–1–8
Treatment	As required	As required	As required	17–4–1 to 17–4–19
Process				
Lowry	Specifications	Specifications	Specifications	17–4–3
Rueping	Specifications	Specifications	Specifications	17–4–3
Bethel	Specifications	Specifications	Specifications	17–4–3
Preservative				
Creosote	Specifications	Specifications	Specifications	17–4–5
Creosote-Coal Tar Solution	Specifications	Specifications	Specifications	17–4–5
Creosote-Petroleum	Specifications	Specifications	Specifications	17–4–5

Schedule of Classes of Complete Roadway and Track Structure Under AREA Recommended Practice—Continued
1954

Item	*Class "A"*	*Class "B"*	*Class "C"*	*Page in Manual*
TIE PLATES				
Material				
Low Carbon Steel	Specifications	Specifications	Specifications	5–1–1
High Carbon Steel	Specifications	Specifications	Specifications	5–1–4
Design				
With 140 RE rail	See Note "B"	See Note "A"	See Note "A"	5–1–7, 5–1–16 to 5–1–20, 5–1–22
With 133 RE rail	See Note "B"	See Note "A"	See Note "A"	5–1–7, 5–1–16 to 5–1–20, 5–1–22
With 132 RE rail	See Note "B"	See Note "A"	See Note "A"	5–1–7, 5–1–16 to 5–1–20, 5–1–22
With 115 RE rail	See Note "B"	See Note "B"	See Note "A"	5–1–7, 5–1–11 to 5–1–15, 5–1–21
With 100 RE rail	See Note "B"	See Note "B"	See Note "B"	5–1–7, 5–1–9 to 5–1–10
With 100 RA-A rail	See Note "B"	See Note "B"	See Note "B"	5–1–7, 5–1–9
With 90 RA-A rail	See Note "A"	See Note "B"	See Note "B"	5–1–7, 5–1–8, 5–1–9
HOLD DOWN SPIKES				
Type				
Screw	Specifications	Specifications	See Note "A"	See Note "B"
Cut	Specifications	Specifications	See Note "A"	5–2–1, 5–2–3
Design				
Screw	See Note "B"	See Note "B"	See Note "A"	See Note "B"
Cut	6 in x 5/8 in & 6½ in x 5/8 in	6 in x 5/8 in & 6½ in x 5/8 in	See Note "A"	5–2–5, 5–2–6
Number per Tie Plate				
Screw	As required	As required	See Note "A"	See Note "B"
Cut	As required	As required	See Note "A"	See Note "B"
RAIL				
General	Specifications	Specifications	Specifications	4–2–1
Section				
140 RE	Fig. 6	See Note "A"	See Note "A"	4–1–6
133 RE	Fig. 5	See Note "A"	See Note "A"	4–1–5
132 RE	Fig. 4	See Note "A"	See Note "A"	4–1–4
115 RE	Fig. 3	Fig. 3	See Note "A"	4–1–3
100 RE	Fig. 2	Fig. 2	Fig. 2	4–1–2
90 RA-A	See Note "A"	Fig. 1	Fig. 1	4–1–1
Drilling				
140 RE	4 or 6 hole	See Note "A"	See Note "A"	4–1–14 to 4–1–15
133 RE	4 or 6 hole	See Note "A"	See Note "A"	4–1–14 to 4–1–15
132 RE	4 or 6 hole	See Note "A"	See Note "A"	4–1–14 to 4–1–15
115 RE	4 or 6 hole	4 or 6 hole	See Note "A"	4–1–14 to 4–1–15
100 RE	4 or 6 hole	4 or 6 hole	4 or 6 hole	4–1–14 to 4–1–15
90 RA-A	See Note "A"	4 or 6 hole	4 or 6 hole	4–1–14 to 4–1–15
Length	39 ft	39 ft	39 ft	4–2–3
Classification	No. 1	No. 1	No. 1	4–2–3

SCHEDULE OF CLASSES OF COMPLETE ROADWAY AND TRACK STRUCTURE UNDER AREA RECOMMENDED PRACTICE—Continued

1954

Item	Class "A"	Class "B"	Class "C"	Page in Manual
JOINT BARS				
Material				
High Carbon Steel	Specifications	Specifications	Specifications	4-2-9
Quenched Carbon Steel	Specifications	Specifications	Specifications	4-2-12
Section				
For 140 RE rail	Fig. 7a	See Note "A"	See Note "A"	4-1-12.1
For 133 RE rail	Fig. 6 or 7	See Note "A"	See Note "A"	4-1-11 to 4-1-12
For 132 RE rail	Fig. 4 or 5	See Note "A"	See Note "A"	4-1-9 to 4-1-10
For 115 RE rail	Fig. 3	Fig. 3	See Note "A"	4-1-8
For 100 RE rail	Fig. 2	Fig. 2	Fig. 2	4-1-7
For 90 RA-A rail	See Note "A"	Fig. 1	Fig. 1	4-1-6.2
Length and Punching				
For 140 RE rail	36 in with 6 holes	See Note "A"	See Note "A"	4-1-14 to 4-1-15
	24 in with 4 holes	See Note "A"	See Note "A"	4-1-14 to 4-1-15
For 133 RE rail	36 in with 6 holes	See Note "A"	See Note "A"	4-1-14 to 4-1-15
	24 in with 4 holes	See Note "A"	See Note "A"	4-1-14 to 4-1-15
For 132 RE rail	36 in with 6 holes	See Note "A"	See Note "A"	4-1-14 to 4-1-15
	24 in with 4 holes	See Note "A"	See Note "A"	4-1-14 to 4-1-15
For 115 RE rail	36 in with 6 holes	36 in with 6 holes	See Note "A"	4-1-14 to 4-1-15
	24 in with 4 holes	24 in with 4 holes	See Note "A"	4-1-14 to 4-1-15
For 100 RE rail	36 in with 6 holes	36 in with 6 holes	36 in with 6 holes	4-1-14 to 4-1-15
	24 in with 4 holes	24 in with 4 holes	24 in with 4 holes	4-1-14 to 4-1-15
For 90 RA-A rail	See Note "A"	36 in with 6 holes	36 in with 6 holes	4-1-14 to 4-1-15
	See Note "A"	24 in with 4 holes	24 in with 4 holes	4-1-14 to 4-1-15
TRACK BOLTS AND NUTS				
General	Specifications	Specifications	Specifications	4-2-15
Design				
For 140 RE rail	1 in x 5¾ in	See Note "A"	See Note "A"	4-1-14, 4-1-16 to 4-1-19
For 133 RE rail	1 in x 5¾ in	See Note "A"	See Note "A"	4-1-14, 4-1-16 to 4-1-19
For 132 RE rail	1 in x 5¾ in	See Note "A"	See Note "A"	4-1-14, 4-1-16 to 4-1-19
For 115 RE rail	1 in x 5½ in	1 in x 5½ in	See Note "A"	4-1-14, 4-1-16 to 4-1-19
For 100 RE rail	1 in x 5½ in	1 in x 5½ in	1 in x 5½ in	4-1-14, 4-1-16 to 4-1-19
For 90 RA-A rail	See Note "A"	1 in x 5¼ in	1 in x 5¼ in	4-1-14, 4-1-16 to 4-1-19
SPRING WASHERS See Note "C"				
General	Specifications	Specifications	Specifications	4-2-19
TRACK SPIKES				
Material				
High Carbon Steel	Specifications	Specifications	Specifications	5-2-3
Soft Steel	Specifications	Specifications	Specifications	5-2-1
Design				
6½ in x ⅝ in	Fig. 1	Fig. 1	See Note "A"	5-2-5
6 in x ⅝ in	Fig. 2	Fig. 2	See Note "A"	5-2-6
5½ in x 9/16 in	See Note "A"	Fig. 2	Fig. 2	5-2-6
Number per tie plate	As required	As required	As required	See Note "B"
RAIL ANCHORS	*			
General	Specifications	Specifications	Specifications	
Number per 39-ft rail	As required	As required	As required	5-5-4 to 5-5-5

NOTES: "A"—This item will not ordinarily be used in this class of Track.
"B"—Recommended Practice not yet determined.
"C"—Spring washers to be used only when Recessed Nuts are not used.
* —Manual Reference For Rail Anchors only. Does not cover Anti-Creepers such as Compression Clips.

SCHEDULE OF CLASSES OF COMPLETE ROADWAY AND TRACK STRUCTURE

For this schedule, which is based on 1954 Recommended Practice and the foregoing Traffic Classification of Railway Main Tracks, and for the report citing the limitations of this schedule, see AREA Proceedings, Vol. 56, 1955, pages 324 to 328, incl.

Report on Assignment 2

Economics of Retarder-Equipped Yards for Classification Switching

Collaborating with Committee 14, Signal Section, AAR, and American Association of Railroad Superintendents

H. A. Lind (chairman, subcommittee), J. W. Barriger, IV, J. M. Bentham, F. N. Nye, F. B. Peter, W. E. Quinn, C. P. Richmond, E. H. Roth, R. F. Spars, T. D. Wofford, Jr., C. A. James, C. W. Sooby.

This is a final report, submitted as information.

The classification or segregation of cars by destinations has presented a perplexing problem ever since the volume of railroad traffic began to attain substantial proportions. Not only has the cost of performing the work been of concern, but in more recent years the delay encountered by cars in yards and terminals has challenged the railroads' competitive ability with other modes of transportation.

In the early days, and in many cases of recent years, it was the practice to 'block' trains only to the next terminal, usually not more than 100 miles away. This system required the rehandling of cars at every district terminal, thereby substantially increasing the transit time of shipments. In the absence of competition, such method of handling did not result in the loss of business, except between railroads.

In the course of time the demand for a more efficient and economical method of operation resulted in the development of 'rider' humps. These increased yard capacity and resulted in better service because blocks of cars could readily be assembled for more distant destinations. However, there were comparatively few such yards, located largely in the eastern part of the country.

With the advent and growth of the trucking industry, the traffic pattern changed substantially by the loss on the part of the railroads of short-haul traffic. For example, the average freight haul for originated tonnage in 1916 was 278 miles, whereas in 1950 it had increased to 417 miles, an increase of 50 percent.

Whereas in past years substantial stock inventories were maintained by industry, such practice has now largely disappeared and patrons demand fast, dependable transportation service to meet the requirements of their businesses. No better illustration of this requirement can be cited than the service which must be provided on automobile parts moving to assembly plants, which are geared to regular and constant day to day deliveries of these parts.

Confronted with these changed conditions, which had to be met in order to continue to enjoy their proper share of the available traffic, the railroads began searching for ways and means to improve their service by reducing the time cars are on the road and in terminals.

The practice of rehandling trains at intermediate terminals presented a burdensome time consumer, so it became of paramount importance that effective 'blocking' of cars for more distant destinations be undertaken at major terminals. Such result has been accomplished by various means and has enabled the 'main tracking' of trains through intermediate terminals, but in most cases the means employed taxed the major terminal facilities beyond capacity, thereby adding to the service problems and car delays. It was here that the 'retarder' yard entered into the picture as an economic method of freight car classification.

Retarder classification yards had their inception in the early Twenties, and today there are 84 such yards in service or under construction in the United States and Canada, with about 10 more in the planning stage. Exhibit "A" lists these classification yards and also shows the number of tracks and the year placed in service, with reference to published articles on some of the improvements. In addition, retarders have been installed in 22 industrial yards to facilitate car handling.

In more recent years, two important adjuncts to retarders have been designed and proved in operation, i.e., Automatic Switching, which by track circuits routes a car or cut to the designated track after one push button has been operated; and Retarder Speed Control, to regulate the movement of cars automatically to a predetermined or selected speed, depending on the weight of car, contents, and other factors, such results being produced either automatically or after the 'selection' by the retarder operator.

In its report on Classification Yards appearing in AREA Proceedings, Vol. 55, 1954, page 429, Committee 14—Yards and Terminals, outlined a number of designs for yard layouts with retarder classification yards. The design of yard should be best suited to the traffic pattern for the particular location, but is often influenced by property limitations, existing installations, topography, or other considerations. Nevertheless, a yard can usually be designed that will fully meet the operating requirements.

The 1953 Proceedings of The American Association of Railroad Superintendents contains an illuminating report on Yard Operations, beginning on page 124, and outlines the basic principles for determining the economic possibilities of terminal improvements.

The economic justification for retarder yard projects has been obtained through:

1. Increased yard and classification capacity, a most essential factor for system-wide or major classification arrangement.
2. More effective classification, frequently on a system-wide basis, that has materially reduced rehandling at other terminals.
3. Substantial reduction in delay time of cars at terminals, thereby improving service to shippers and resulting in considerable savings in per diem expenses. For one large railroad the saving in car time averaged 12 hr, as set forth in reference material listed herein.
4. Reduced loss and damage to equipment and lading, and in personal injuries sustained by yard operating personnel; all contributing to reduced operating expenses.
5. Reduced manpower requirements, with resultant lower terminal operating costs.
6. Reduced switch engine requirements, with savings in operating costs, as well as reduced investment in yard power.
7. Increased train load, usually made possible by having cars classified and available for movement sooner, and through reduction in terminal time with earlier train departures—train need not run so fast to maintain advertised schedules, so increased tonnage per train has resulted. Increased train tonnage has naturally reduced freight train miles and operating expenses.

EXHIBIT A

RETARDER CLASSIFICATION YARDS—UNITED STATES AND CANADA

Railroad	*Location*	*No. of Class. Tracks*	*Year in Service*	*Publication Reference*
AT&SF	Argentine, Kan.	56	1949	RA 11- 5-1949
AT&SF	Pueblo, Colo.	16	1950	RA 6-11-1951
B&O	E.B., Willard, Ohio	32	1948	RA 10-23-1948
B&O	W.B., Willard, Ohio	20	1948	RA 10-23-1948
B&O	E.B., Cumberland, Md.	16	1947	RS July 1948
B&O	Lorain, Ohio	5	1947	RA 1-31-1948
B&O	Connellsville, Pa.	15	Under Const.	
Belt Ry of Chgo.	W.B., Clearing, Chicago	36	1938	RS Aug. 1948
Belt Ry of Chgo.	E.B., Clearing, Chicago	56 (1)	1953	RS Aug. 1948
B&M	In Bound, Boston, Mass.	47	1927	RS July 1928
B&M	Out Bound, Boston, Mass.	30	1927	RS July 1928
B&M	Mechanicville, N. Y.	36	1927	RS Mar. 1928
CPR	St. Luc Yard, Montreal, Que.	48	1950	RA 8-12-1950
CRR of NJ	E.B., Allentown, Pa.	24	1927	
CRR of NJ	W.B., Allentown, Pa.	22 (2)	1952	RA 11- 3-1952
C&O	W.B., Walbridge, Ohio	68	1948	RA 7-31-1948
C&O	W.B., Russell, Ky.	52	1949	
C&O	Stevens, Ky.	15	1954	
CB&Q	E.B., Galesburg, Ill.	49	1931	RA 12-24-1932
CB&Q	W.B., Galesburg, Ill.	35	1942	
CB&Q	Lincoln, Nebr.	36	1944	RA 7-21-1945
CCC&StL	W.B., Sharonville, Ohio	30	1929	RS Dec. 1929
CCC&StL	Sharonville, Ohio	15	1952	
CMStP&P	Airline, Milwaukee, Wis.	25	1952	RA 6-30-1952
CMStP&P	Bensenville, Ill.	70	1953	RA 7-13-1953
C&NW	Proviso, Ill.	59	1929	RS June 1930
CRI&P	Armourdale, Kan.	40	1949	RA 7-16-1949
CRI&P	Silvis, Ill.	50	1949	RA 1-28-1950
DL&W	Hampton, Scranton, Pa.	29	1937	RS Jan. 1938
D&RGW	Grand Junction, Colo.	24	1953	RA 10-19-1953
EJ&E	Kirk, Gary, Ind.	58	1952	MR Oct. 1953
Erie	W.B., Marion, Ohio	24	1931	MS Apr. 1931
IC	N.B., Markham, Homewood, Ill.	64 (2)	1952	
IC	East St. Louis, Ill.	26	1926	RS Mar. 1950
IC	S.B., Markham, Homewood, Ill.	45 (3)	1950	RA 6-17-1950
IHB	Blue Island, Ill.	41 (2)	1953	RA 12-14-1953
IHB	N.B., Gibson, Ind.	30	1924	
IHB	S.B., Gibson, Ind.	30	1926	
LV	Coxton, Pa.	17	1928	
LV	E.B., Oak Island, N. J.	38	1930	
LV	W.B., Oak Island, N. J.	15	1930	
L&N	N.B., DeCoursey, Ky.	20	1940	
L&N	Radnor, Nashville, Tenn.	56	1954	
Mich Cent	W.B., West Detroit, Mich.	31	1930	RS Mar. 1930
Mon Conn	Eastern Yard, Pittsburgh, Pa.	22	1949	
NYC	W.B., Selkirk, Near Albany, N. Y.	25	1928	RS May 1928
NYC	W.B., DeWitt, Syracuse, N. Y.	27	1928	
NYC	E.B., DeWitt, Syracuse, N. Y.	40	1929	
NYC	Gardenville, N. Y.	31	1930	
NYC	Stanley, Ohio	42	1931	RS Sept. 1931
NYNH&H	Hartford, Conn.	26	1926	RA 11- 3-1928
NYNH&H	Providence, R. I.	34	1929	RS Jan. 1931
NYNH&H	E.B., Cedar Hill, New Haven, Conn.	45	1929	RS Dec. 1933
NYNH&H	W.B., Cedar Hill, New Haven, Conn.	38	1929	RS Dec. 1933
NYC—OCL	Toledo, Ohio (Dumper)	7	1929	RS Jan. 1930
N&W	W.B., Portsmouth, Ohio	35	1928	
N&W	E.B., Roanoke, Va.	46	1942	
N&W	Portsmouth, Ohio (Time Freight)	18	1942	
N&W	Bluefield, W. Va.	13	1954	
N&W	Lamberts Point, Norfolk, Va.	30	1952	
NP	Pasco, Wash.		Under Const.	
PRR	E.B., Pitcairn, Pa.	34	1929	RS July 1930
PRR	W.B., Enola, Pa.	36	1944	
PRR	W.B., Pitcairn, Pa.	41	1946	
PRR	W.B., Conway, Pa.	56	Under Const.	
PRR	E.B., Conway, Pa.	54	Under Const.	
PRR	E.B., Enola, Pa.	33	1937	RS Nov. 1938
QNS&L (Iron Ore Co.)	Seven Islands, Que.	12	Under Const.	
Reading	W.B., Rutherford, Pa.	18	1950	RA 10-27-1952
Reading	E.B., Rutherford, Pa.	33	1951	RA 10-27-1952
RF&P	N.B., Potomac, Alexandria, Va.	46	1930	RA 3- 5-1932
RF&P	S.B., Potomac, Alexandria, Va.	29	1945	

EXHIBIT A

RETARDER CLASSIFICATION YARDS—UNITED STATES AND CANADA—Continued

Railroad	*Location*	*No. of Class. Tracks*	*Year in Service*	*Publication Reference*
SAL	Hamlet, N. C.	80	Under Const.	
Southern	Sevier Yard, Knoxville, Tenn.	46	1950	MR Sept. 1951
Southern	Norris Yard, Birmingham, Ala.	56	1952	RA 11–10–1952
Southern	Citico Yard, Chattanooga, Tenn.	60	Under Const.	
SP	Taylor, Los Angeles, Calif.	40	1949	RA 5–27–1950
SP	Roseville, Cal.	49	1952	RA 1– 5–1953
SP (T&NO)	Englewood, Houston, Tex.	48	Under Const.	
T&P	Lancaster Yard, Fort Worth, Tex.	32	1928	RS Aug. 1928
Toledo Dock & RR Term.	Toledo, Ohio	12	1948	
Union	Mon. Southern (Pittsburgh, Pa.)	23	1954	
UP	Pocatello, Idaho	40	1947	RS Jan. 1948
UP	North Platte, Nebr.	42	1948	RA 10–30–1948

(1) Enlarged
(2) Enlarged and Modernized
(3) Modernized
Note: In addition, there are about 22 retarder installations for car dumper and other industry operations.
RA Railway Age
RS Railway Signaling
MR Modern Railroads

September 9, 1954

System-wide studies by a number of railroads have clearly demonstrated the economic feasibility of the retarder method of car classification, and studies comparing operations before and after retarder yard installations have proved the wisdom of the undertaking. The following references are given to published economic reports.

Pocatello, Idaho—Union Pacific R. R., AAR, Sig. Sec. Advance Notice 1954, Vol. LI No. 1, p. 11–a.

Russell, Ky.—Chesapeake & Ohio Ry., AAR, Sig. Sec. Advance Notice 1950, Vol. XLVII No. 1, p. 22.

Walbridge, Ohio—Chesapeake & Ohio Ry., AAR, Sig. Sec. Advance Notice 1950, Vol. XLVII, No. 1, p. 25.

North Platte, Nebr.—Union Pacific R. R. AAR, Sig. Sec. Advance Notice 1951, Vol. XLVIII, No. 1, p. 28.

Knoxville, Tenn., and Birmingham, Ala.—Southern Railway, New York Railroad Club Proceedings, Nov. 1953, p. 6.

1953 Proceedings of The American Association of Railroad Superintendents, dealing with Yard Operations, p. 124.

This report has been submitted to and received the endorsement of all of its collaborators.

Report on Assignment 3

Cause and Effect of Derailments and Dragging Equipment

Collaborating with Committees 3 and 5

W. E. Quinn (chairman, subcommittee), J. J. Corcoran, Allen Hazen, H. C. Hutson, R. J. D. Kelly, A. E. MacMillan, H. P. Morgan, C. L. Towle, H. P. Weidman, H. L. Woldridge, L. K. Sillcox.

This is a final report, presented as information.

To develop a report on this assignment, two questionnaires were sent out to all members of Committee 16, representing 32 railroads. Six replies were received. Four of the replies furnished such information as was available on the member's railroad and two reported that it was impossible to obtain any worthwhile data from their railroad's records.

Of the answers received from 4 of 32 railroads, only 3 presented the data in such shape that comparison and analysis could be made from the reports. The 3 roads reported on 235 derailments, with total damage of $1,379,646.

Of the 235 derailments, 90, with damage of $902,151, were caused by equipment failure; 22, with damage of $132,913, were caused by failure of track; 82, with damage of $150,064, were caused by employee failures and 41, with damage of $194,518, were attributed to miscellaneous causes.

Of the equipment failures, first in line are wheels and axles, which accounted for 33 derailments, with damage totaling $401,698. Of this classification, broken or burned off journals accounted for 14 derailments, with damage amounting to $340,565; broken wheels and flanges caused 11 derailments, with damage of $48,332; and loose wheels caused 8 derailments, with damage totaling $12,801.

Second in line of equipment failures are car bodies and other parts of equipment, which caused 31 derailments, with damage of $250,403.

Third in line is brakes, brake rigging and appurtenances, which caused 15 derailments and damage of $82,757. This is followed by draft rigging failures, which caused 9 derailments and damage of $163,112.

No separation is made of derailments caused by dragging equipment, but they are included in the three preceding paragraphs.

The method used on most of the railroads in reporting on accidents or derailments is that immediately following an accident or derailment the section foreman on the territory involved files an accident report with the division engineer and shows thereon his estimate of the amount of material and labor required to repair the immediate damage to track, and an estimate of cost to rerail the equipment and clear the derailment. These reports are sent by the division engineer to the division superintendent, who in turn secures an estimate of equipment damage and claims for lading, if any are involved, and reports the derailment to the general manager. The general manager uses the superintendent's report as a basis for report to the Interstate Commerce Commission, if the amount involved exceeds the ICC limitation of $325.

The actual accounting for the derailment damage is shown on the section foreman's time and distribution sheets, and in the case of damage to equipment on the shop repair report. These reports are sent to the accounting department, which charges off the cost of clearing wrecks to Account No. 415, the repairs to equipment to the appropriate operating expense account, and the repairs to track to appropriate MW&S operating expense accounts. Complete accounting of the cost of any particular derailment is not kept except in cases where the cost is billed against an industry or other railroad.

No separation is shown for the damage done by dragging equipment, and unless the dragging equipment results in a derailment, reports are seldom made.

In study of the assignment, and from conversation with accounting officers from various railroads, the fact was developed that on most roads very few permanent and accurate records are kept of the cost of derailments.

The lack of complete accounting records kept on the cost of derailments on most of the roads is probably the reason for the very meager response to the committee's questionnaires.

The 1952 Interstate Commerce Commission Accident Bulletin No. 121 (latest available) reported 5783 derailments, with damage to railway property of $28,359,454, as shown by the following tables:

DERAILMENTS 1952—ICC ACCIDENT BULLETIN 121

Class and Cause	*Number of Train Accidents*	*Damage to Railway Property*
Negligence of employees	1,134	$ 1,859,537
Defects in or failures of equipment	2,476	16,029,962
Defects in or improper maintenance of way and structures	1,212	5,305,147
Miscellaneous	961	5,164,808
Total derailments	5,783	$28,359,454

DERAILMENTS DUE TO DEFECTIVE EQUIPMENT

Class and Cause	*Number of Train Accidents*
Broken axles and journals due to overheating and other causes	831
Broken wheels and flanges	343
Loose wheels	139
Defective brakes, brake rigging and appurtenances	275
Couplers and draft rigging	335
Car bodies and other parts of equipment	123
Miscellaneous equipment failures	430
Total	2,476

In view of the enormous cost of derailments, which in 1952 amounted to $28,359,454, the attention of the operating officers of the railroads should be directed to this report in order that in this period of rising costs and decreasing railroad revenue their efforts may be intensified so that, through increased supervision and inspection of track and equipment, the number of derailments may be reduced and a large part of this useless expense eliminated.

Report on Assignment 4

Economics of "Highway Trailers on Flat Cars" Service

Collaborating with the American Association of Railroad Superintendents

F. N. Nye (chairman, subcommittee), Q. K. Baker, J. W. Barriger, W. J. Harlow, J. E. Jay, E. C. Poole, W. E. Quinn, L. K. Sillcox, P. J. Schmitz, H. M. Shepard, D. S. Sundel, C. W. Sooby, G. H. Tilson.

This is a progress report, submitted as information.

Transportation of highway trailers on railroad flat cars is not a recent innovation to the railroad industry. The Long Island Railroad, beginning in 1885 and for several years thereafter, operated so-called "Farmers' Trains" between Long Island points and the East River at New York, carrying four loaded produce wagons per flat car, with the teams riding along on the same train in box cars built expressly for that purpose. As early as 1926 the Chicago, North Shore & Milwaukee pioneered this service by handling their less-than-carload freight in trailers loaded on flat cars between Chicago and Milwaukee, Wisc. Since that time other individual railroads have provided such service, but for various reasons, including lack of sufficient traffic, the absence of balanced loads in both directions, service and rates, they were apparently unable to expand the operations. In 1936 a mid-west railroad (Chicago Great Western) set up such a service between Chicago and St. Paul, Minn., and the following year an eastern road (New York, New Haven & Hartford) undertook an operation between New York and Boston, Mass. Both of these have continuously developed—used principally by motor common carriers—and have proved to be a source of attractive revenues to the railroads, and apparently a means of saving over-the-road costs to the participating motor carriers.

Although introduced nearly 20 or 30 years ago, trailer-on-flat-car service has made most of its headway since World War II. This interest on the part of the railroads is undoubtedly due to the inroads made by other means of transportation and resultant loss of traffic. The motor carrier's interest arises from ever-increasing unit costs.

The nation's output of goods and services has steadily increased and the total volume of freight transported has kept pace. The ton mileage of all freight has generally increased year by year since 1939. The rise was temporarily interrupted in 1945–1946 when gross national production dropped during reconversion, and in 1949, a recession year. In 1939 the railroads' share of total intercity ton miles was 62.3 percent. At the wartime peak (1943) it was 71.3 percent; today it is down to about 54 percent. The trucks' share dropped from 9.7 percent to 5.5 percent during the war, but it has since soared, and today stands at about 17 percent of the total. Using the average of the 1947–1949 period (Federal Reserve Board index basis) as 100 percent—total intercity ton miles today stand at 119 percent—railroads 101.4 percent and motor vehicles 213.1 percent. It is apparent that railroad traffic is not keeping pace with production trends; the rail carriers are losing ground to the motor carriers.

The ever-increasing diversion of tonnage from rails to motor carriers is a matter of grave concern to the railroad industry, and indeed to our national economy. Changes in modes of transportation, length of haul, and the nature of commodities transported are always taking place. Transportation is not static. Due to technological advancement, the great expansion of publicly financed highways, and general economic and social trends, rail transportation finds itself faced with increasingly formidable competition.

A shipper chooses his freight service according to (1) availability, (2) speed and safety, (3) cost. Railroads have in theory at least a big advantage in overall costs—all elements considered—and are potentially capable of surpassing the trucks in speed of service. Their advantage increases as the length of haul increases. But in availability and flexibility of service, particularly in terminal areas or on short hauls, the trucks have a big off-setting advantage. Truck service is very flexible as the operating unit is small and the service is practically universal since it can pick up and deliver anywhere that can be reached by highway. Prior to the coming of the motor truck, new industry located along railroad tracks or water fronts where other industries had long since located either through zoning laws or the need to have ready access to transportation.

Locations along the railroad tracks or waterfronts are no longer essential to many industries. Suburbanization of the nation's population and the decentralization of industrial centers have been partly responsible for the swing away from the railroads. Highways have followed—indeed have influenced—the shift of freight business; railroads are long past their era of large-scale location and construction. Many new industries and communities are now largely dependent upon motor carriers.

Due to the diversion of traffic from rails to motor carriers, and in an effort to regain their position in the transportation market, railroad managements in the past couple of years have given trailer-on-flat-car service serious consideration. It may provide means whereby railroads can increase their revenues, either directly through holding out a railroad-trailer service under truck competitive rates, or through joint arrangements with motor carriers which may use the service in cooperation with the railroad. Whether or not to provide the service, the choice between these methods, or the holding out of both methods, is a matter of traffic judgment. The implications in choice have been before the Interstate Commerce Commission in Docket No. 31375, as will be explained later.

Since the first loading of trucks or trailers on flat cars in the 1920's many railroads in the United States and two in Canada have had limited trailer-on-flat-car service at one time or another.* For most the experiment was brief. Review of these "failures" indicates that although the charges assessed were reasonable, the rail service was not dependable, traffic was not well balanced between terminals, handling costs were too high, and the carriers encountered labor difficulties.

However, in 1953 a few railroads inaugurated this service on a limited scale.#

* The railroads having trailer-on-flat-car service at one time or another are:

Atchison, Topeka & Santa Fe
Chicago, & Alton (now Gulf, Mobile & Ohio)
Chicago, Burlington & Quincy.
Chicago & Eastern Illinois
Chicago Great Western
Chicago, North Shore & Milwaukee
Chicago, Rock Island & Pacific
Chicago, South Shore & South Bend
Canadian National
Canadian Pacific
Denver & Rio Grande Western
Detroit & Mackinac
New York, New Haven & Hartford
Southern Pacific
Texas & New Orleans
Union Pacific
Wabash

Railroads that inaugurated this service in 1953:

Chicago & North Western
Southern Pacific
Union Pacific
Canadian National
Canadian Pacific

Thus far in 1954 several railroads$^{\phi}$ have announced plans for trailer-on-flat-car services and the programs in force on other lines have been extended to new points.

A brief outline of representative rail carriers presently offering trailer-on-flat-car service follows:

Chicago, Burlington & Quincy—The CB&Q since 1937 has operated a trailer-on-flat-car service between Chicago and Galesburg, Ill., a distance of 162 miles, for its wholly owned subsidiary, the Burlington Transportation Company. At the present time modified flat cars are assigned to the service. An experimental service has recently been started between Chicago and Kansas City, Mo. If this proves successful it may be extended to Omaha, Nebr.

Chicago & Eastern Illinois—In 1950 this railroad established this service between Chicago and Mitchell, Ill. (St. Louis). It is used principally by one trucking concern. The railroad has about 40 cars assigned to the service and provides the terminal facilities. Loading and unloading are over end ramps extending from ground level to car floor. The motor carrier must load and unload the trailers, but railroad employees fasten the vehicles on the cars at origin and unfasten them at destinations. It takes about 5 to 6 min to secure the tie-down equipment and about 3 min to unfasten it.

Southern Pacific—On May 4, 1953, this road started handling trailers, loaded with its own LCL freight, on specially equipped flat cars to provide first morning delivery between Houston, Tex., and certain cities in Louisiana. In August 1953 it started the first such operation on the West Coast between Los Angeles and San Francisco, a distance of 482 miles. Service is limited to trailers of its subsidiary—Pacific Motor Trucking Company.

Chicago & North Western—In August 1953 the C&NW inaugurated a trailer-on-flat-car operation between Chicago and Green Bay, Wisc., a distance of 201 miles. In this operation the railroad's LCL shipments are loaded in trailers of the C&NW pick-up and delivery service, in delivery order, which coordinates local handling in Chicago and Green Bay with rail service between these points.

The carrier initially modified four standard flat cars to accommodate two trailers on one car. This operation was successful, and to date the service has been expanded on four occasions to include Omaha, Nebr., St. Paul and Minneapolis, Minn., and Milwaukee, Wisc. The C&NW now holds itself out, under its own published rates, to handle trailers for account of individual shippers. This is merely a modified container service—the container in this case being a body on wheels, i.e., a semi-trailer. End ramps for the loading and unloading of the trailers have been installed at all terminals where the service is provided. Experimental use has also been made of lightweight portable ramps.

Union Pacific—In August 1953 the UP inaugurated an experimental operation between Los Angeles, Calif., and Las Vegas, Nev. On November 30, 1953, the service was extended between Los Angeles and Salt Lake City, Utah, and further extensions are contemplated.

ϕ The railroads announcing plans for trailers-on-flat-cars in 1954:

Baltimore & Ohio
Delaware, Lackawanna & Western
Erie
Great Northern
Lehigh Valley
Missouri–Kansas–Texas
New York Central
New York, Chicago & St. Louis
Northern Pacific
Pennsylvania
Reading
Wabash

Canadian National and Canadian Pacific Railways—In December 1953 these railways started handling a limited number of their own trailers carrying LCL freight between Montreal, Que., and Toronto, Ont., a distance of 335 miles.

In the main, these operations are small and frequently limited to rail LCL or trailers of subsidiary companies. In all cases the trailers are loaded over inexpensive inclined end ramps to the cars and then from flat car to flat car over folding bridge plates or aprons that are part of the cars' special equipment. In the majority of cases only a few cars are handled daily and move in regular freight train service.

The two so-called "grandfathers" of trailer-on-flat-cars are the Chicago Great Western and the New Haven Railroads, their operations, briefly, are as follows:

Chicago Great Western—This road originally filed a tariff covering the handling of trailer-on-flat-cars to become effective March 1, 1936, the service to be provided between Chicago and St. Paul, Minn. The tariff was suspended by the ICC, but after hearing was allowed to become effective July 7, 1936. Trailers on CGW flat cars have been operating ever since and the service has expanded to include Council Bluffs and Des Moines, Iowa, and Kansas City, Mo. The service is confined solely to motor common carriers.

Ordinary flat cars measuring 53 in length are equipped with guard rails on both sides, chuck blocks to fit in front of and behind the rear wheels of the trailer, and screw-top jacks to support the front end of the trailer. Chains with turnbuckles extend from the floor of the flat car to fastenings on the trailers to hold them firmly in place on the car.

Parking lots are provided adjacent to the loading and unloading ramps. The actual loading and unloading is performed by a terminal employee of the truckers, and this cost is prorated among the participating motor carriers. Railroad employees secure the tie-down equipment.

The railroad maintains ramps and docks at the ends of stub tracks at all terminals where the service is provided. The flat cars are handled in regular train service.

When the service was first started it was used by 17 motor common carriers. Today it is used by more than 40. The service over the years has been a source of substantial revenue. Last year it grossed over $1 million.

New York, New Haven & Hartford—Trailer-on-flat-car services are operated on the New Haven between New York and New Haven, Conn., Springfield, Mass., Providence, R. I., and Boston, Mass., as well as between Boston and New Haven. This service, known as "Trailiner", was started in 1937 and has been in continuous operation since that time.

In the earlier years there was not much demand for the coordinated rail-truck service, but in recent years it has expanded rapidly. In 1953 more than 50,000 trailers were handled on New Haven flat cars, the largest volume in the history of the service, and a nearly 10 percent greater volume is being attained in 1954. It is an important element of the New Haven's freight traffic.

The service is available to all motor common carriers holding the rights between points where schedules are provided and who comply with ICC regulations. It is also held out to private carriers, who are free to use the service without federal or state operating rights, and, in addition, the railroad transports some trailers containing its own LCL. This latter represents less than one-half of one percent of the total handled. All trailers tendered for movement must meet standards, dimensions and specifications set up by the railroad's mechanical department.

Although the service is held out to individual shippers, this has not been encouraged as there is no regularity of round trip movement. Motor common carriers, however, provide loaded trailers in both directions.

A fixed charge per loaded trailer is published between points served regardless of the commodity loaded therein, and assessed against private shipper. A somewhat lower charge named in a division sheet is collected from motor common carriers—to reflect volume of traffic and balanced movement.

All trailers are weighed by the railroad, and when loaded in excess of a specified gross weight a further charge is assessed for the excess weight. Empty trailers are handled only in reverse of loaded movement of such trailers—generally at one-half the loaded rate.

The trailers of common motor carriers are transported under authority of the "Substituted Freight Service Directory". The movement may be a joint motor-rail-motor movement, i.e., rail service may be substituted for highway service on part of the haul. For example, on a common motor carrier movement from Philadelphia, Pa., to Bangor, Me., rail service may be substituted for that portion of the haul between New York and Boston. The charges assessed by the railroad for the transportation of trailers of common motor carriers are, in effect, as noted above, a division of the through motor carrier rate and are named by the railroad in its own division sheet. The railroad proportion of the rate, as a practical matter, is related to the common motor carrier's cost per vehicle mile between the same points. It must slightly under-cut the motor carrier's over-the-road costs to attract his business, yet be high enough to more than cover the railroad's out-of-pocket costs and yield a profit. The area of negotiation is a rather limited one.

The motor carrier tenders or receives the semi-trailers at the railroad's trailer yard. Stub tracks for the exclusive handling of the trailers are served by permanent end ramps. The loading or unloading of the trailers is the so-called "circus type" previously outlined. The physical loading and unloading and the tying down of the trailers are performed by a trucking subsidiary of the railroad and the railroad pays its subsidiary for this service.

The New Haven currently utilizes a fleet of over 300 flat cars in balanced movement between key points on a 48-hr turnaround basis—eastbound one night, and returning westbound the following night. These cars are 40 ft long, equipped with high-speed trucks and anti-hot-box appliances. The cars were specially designed and constructed in the New Haven shops; additional cars are under construction. The New Haven handles only one trailer to a car. From an operating standpoint it does not consider 70 to 75-ft flats as satisfactory or as efficient as 40-ft cars.

Special freight trains in trailer service are operated daily, except Sunday, on overnight schedules. The New York to Boston schedule is 6½ hr, an average of 32 mph. Overnight operation and the maintenance of advertised schedules are the key to the success of such operation and an influencing factor in its use by highway motor carriers.

At the present time most carriers performing trailer-on-flat-car service are generally using conventional flat cars not exceeding 55 ft in length, which have been provided with side rails and special mechanical tie-down devices. End aprons or bridges fold out to span between cars to permit circus-type loading. When trailer-on-flat-car operations were first inaugurated, semi-trailers were about 20 to 26 ft long and, by matching, two trailers could ordinarily be loaded on one flat car. Over the years the length of trailers has increased, and today they range from 28 to 35 ft, and generally only one trailer can be loaded on a normal size flat car.

Highway carriers are so highly competitive among themselves that an individual operator cannot afford to become saddled with any arrangement or specialized equipment that might put him at a disadvantage in meeting competition of other truckers. If the operation is to be successful, large numbers of trailers must be efficiently handled. They must be promptly loaded and unloaded in a manner that will not entail unreasonable terminal expense. End loading of cars has proven practicable where sufficient tracks are available to spot short cuts of cars. Various suggestions for using giant fork lifts, gantry or revolving cranes, portable end ramps, side loading from high level platforms, etc., have been made. Each railroad must evaluate proposed terminal facilities in the light of prospective traffic volume, the relative capital costs and carrying charges, and the probable operating costs as influenced by different types of facilities and equipment to be used.

Within the past year a new type 75-ft flat car has been designed with a depressed deck and raised ends, equipped with fixed stanchions and tie-down devices. The depressed car floor enables the handling of trailers with a maximum legal height of 12 ft 6 in, without exceeding the standard 15-ft height for freight equipment. It also makes for a lower center of gravity and so permits faster movement with safety. It is designed to accommodate two present-day trailers loaded back to back. This type of car precludes end or circus loading. The use of such equipment will require special and rather costly terminals so trailers may be side loaded. For example, such a terminal designed to handle a 50-car train carrying 100 semi-trailers might have a single depressed track 4000 ft in length with an adjacent paved driveway and parking area. It would, however, generally be more practical for it to contain 4 depressed tracks of sufficient length that each track could hold 12 or 13 cars. There would be inter-track and flanking driveways and adjacent parking area. With side-loading equipment, end ramps are not necessary, so it is feasible to connect the terminal layout to the main tracks at each end to speed up switching. Such a terminal should be conveniently located to the city's truck terminal district and have ready access to yard switchers to insure the prompt pulling and placing of the cars.

The side loading and unloading of the trailers would be performed by a special fork-lift tractor. This type of handling is said to have the advantage of speed; two or more unloading crews can work simultaneously on a single cut of cars. It permits flexibility and economy of operation where large train-load volume of business is available at major cities. The objection to such an operation is that depressed track terminals cost at least twice as much—and perhaps more—as end loading facilities. It may also lead to higher taxes and maintenance costs. However, with adequate volume operating economies may offset the greater capital cost and hold total costs to approximately the same level.

More recently, one of the largest car builders has completed the preliminary design for an all-purpose flat car. It will, they declare, permit either side or end loading of trailers. A feature of the design includes 2 sets of elevators built into the center of the 75-ft car as optional equipment. The elevator mechanism allows the trailer wheels to be lowered into the flat car bed, thus lowering the clearance and center of gravity. The flat car also can be used for general purposes when the elevator wells are raised to create a flat deck.

With specialized and costly equipment and expensive side-loading terminal installations the operation depends upon large volumes of balanced traffic to make it a success. A logical source of such business—as the New Haven and Chicago Great Western operations have demonstrated—is from motor common carriers. To satisfy their schedule requirements, and to handle most efficiently the volume of traffic they can provide, solid trailer trains should be operated where possible. To develop the inherent advantage of the railroad—long-haul mass transportation—the routes should be between major cities between which traffic can be concentrated to support the investment. The motor carrier, whose inherent advantage is flexible, short haul and terminal distribution, can then complete the movement to and from the terminal cities.

A motor carrier's over-the-road cost per trailer mile varies, depending on the nature of his traffic and on the section of the country in which he operates. Wages, licenses, taxes, including ton mile or axle imposts, vary from state to state. Operators in New England have the highest costs, which diminish into the South and West. The national average of direct over-the-road costs is approximately 25 to 30 cents per trailer mile. Trailers-on-flat-car service must be sold on terms which approximate, or slightly undercut, the trucker's average cost per trailer mile. On this basis a 50-car train with 2 loaded trailers per car could produce gross revenue up to about $25 per train mile. Actually, the revenue would be somewhat less because some of the trailers might be returning empties producing only half the revenue of a loaded trailer.

Each railroad considering such an operation must evaluate the potential revenue in terms of its own direct operating expenses—both line haul and terminal—and the cost of providing and maintaining the specialized equipment and terminal facilities. These costs must be further considered in the light of motor carrier, direct over-the-road costs in the same territory. This will develop a "zone of negotiation" for an agreement as to divisions where joint operations are contemplated. Its traffic officers must evaluate the availability of traffic—whether under rail tariffs or under joint arrangements with motor carriers—and whether or not the attracted traffic will become a permanent part of the operation or merely a service of convenience to the highway operators.

As to labor's attitudes, the Railroad Brotherhoods encourage the handling of highway trailers on railroad flat cars. On the other hand, the Teamsters Union shows little enthusiasm for it; they now have the matter under study. In 1952 a Teamsters local picketed the New Haven loading yard at Boston and the railroad was forced to obtain an injunction to prevent the disruption of its service. The Teamsters Union may insist on maintaining jobs for its members. It may well be, however, that the coordinated rail-truck service will, in the long run, make for more teamster's jobs—in terminal distribution—which will offset any slight loss in over-the-road jobs. Also to be considered is that continued growth in trucking, such as has occurred since the war, will of itself provide a new pool of potential traffic, and so obviate elimination of any names from the present roster of over-the-road drivers.

It is no longer realistic to look the other way and pretend that trailer-on-flat-car service isn't here. Trailers-on-flat-cars is a live issue and decisions of far reaching consequences must soon be made. Many railroads have already made their decisions, but some controversial problems still remain.

On September 30, 1953, the New Haven Railroad petitioned the ICC for a declaratory order, under the Administrative Procedure Act, to provide answers to certain queries which relate to broad overall questions as to whether or not the New Haven may legally restrict its "holding-out" to motor common carriers, and if not, what are its obligations to the public? It asked the rulings to avoid any operation which might directly or indirectly violate the provisions of the Interstate Commerce Act. The ICC issued a notice on January 6, 1954, initiating a proceeding to be known as *Movement of Highway Trailers by Rail,* Docket No. 31375.

The commission expressed its willingness to receive suggestions and representations from interested parties. The notice indicated that the commission planned the formulation or construction of "proposed rules governing this area of transportation". In response to the notice, many interested parties submitted suggestions, petitions and other pleadings. There was rather general agreement that the commission should not publish rules for this type of operation as no broad experience now existed on which to build such rules. On April 19, 1954, the commission withdrew its intention to enlarge the case to include "rule making". The original 20 questions of the New Haven and questions raised by others have been reduced to 12 and reframed in such manner as to pose the basic legal questions involved. The issues raised by the questions were heard in oral argument at Washington on June 28, 1954. The railroads defended their right to perform this service; the motor carriers tried to claim it was a form of motor carriage requiring certificates under Part II of the Act.

On July 30, 1954, the commission made its report with the following general findings:

A railroad may transport its own freight (i.e., freight tendered to it by shippers for movement by railroad, on railroad bills of lading and at railroad rates) in its own trailers on flat cars, without holding any authority under Part II of the Act. This is rail transportation rather than highway transportation, and it includes the right to make a terminal pick-up and delivery of the trailers.

(Note: These same issues are still before the commission in I&S 6214, involving tariffs published by the PRR, Erie, DL&W, NKP, B&O and Wabash. The commission suspended these tariffs on June 14, just before they were to become effective. A few days later the suspension was lifted and the matter set for hearing on July 27. It has been recessed to October 12, following a stipulation that the railroad respondents will furnish the motor carrier protestants with information on which a cost study can be based. It would appear that the issues in this I&S case have already been resolved by the July 30 order.)

A railroad may also transport on its flat cars the trailers of private shippers and freight forwarders under its open tariffs.

As to contract motor carriers, they can only take advantage of the railroad's trailer-on-flat-car service and tariffs beyond the territorial limits of their own certificates, in which case they act as agents for the shipper.

Motor common carriers can ship trailers under tariffs open to the general public or under division arrangements if they have first established through route and joint rate arrangements. These arrangements are not compulsory; railroads have the option of establishing them with motor carriers of their own choice and refusing them to others. Whether or not a railroad can limit its services solely to motor common carriers depends on the circumstances in particular cases, the nature of the operation and the reasonableness of the request by others for like service.

The success of trailer-on-flat-car operations will depend upon three fundamentals, which involve cooperation between the railroad and the highway participants, be they motor carriers, forwarders, or private carriers:

1. Establishing and maintaining schedules that will equal or better the motor carriers' over-the-road time.
2. Establishing rates or charges competitive with those published by motor carriers, or divisions no greater than the motor carriers' present cost of hauling over-the-road. They must be low enough to attract highway traffic, yet high enough to be worthwhile to the railroads.
3. The design of equipment and the type of terminal facility to be used must be sound from the engineering, operating and economic standpoints.

4. Railroads providing this service should give careful consideration to uniformity of equipment and terminal design. Standardization will promote expansion of local operations into interline services—which historically have led to an improved railroad industry.

Trailer-on-flat-car service has received widespread carrier, shipper and public interest. It has been the subject of considerable press comment, both news and editorial. It has been the subject of resolutions adopted by traffic, carrier and labor groups of national scope. Its growth is spreading to major railroads from coast to coast. It poses many problems—principally of a traffic nature. If these can be resolved, it holds promise of being a forward step in transport coordination.

Report of Committee 13—Water, Oil and Sanitation Services

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C. L. Waterbury
J. E. Wiggins, Jr.
E. L. E. Zahm
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Types of corrosion in railway water and fuel service, collaborating with Mechanical Division, AAR.

   Progress reported, without formal report.

3. Federal and state regulations pertaining to railway sanitation, collaborating with Joint Committee on Railway Sanitation, AAR.

   Progress report, presented as information .... page 344

4. Mechanics of foaming and carry-over in locomotive boilers, collaborating with Mechanical Division, AAR.

   No report.

5. New developments in water conditioning for diesel locomotive cooling systems, collaborating with Mechanical Division, AAR.

   Progress report, presented as information .... page 345

6. Railway waste disposal, collaborating with Joint Committee on Railway Sanitation, AAR.

   Progress report, presented as information .... page 346

7. Treatment of water for cooling purposes.

   Progress report, presented as information .... page 347

8. Diesel oil and water servicing facilities, collaborating with Mechanical Division, AAR.

   Progress report, presented as information .... page 355

9. Disinfectants, deodorants, fumigants, and cleaning materials, collaborating with Joint Committee on Railway Sanitation, AAR.

   Progress in study, but no report.

THE COMMITTEE ON WATER, OIL AND SANITATION SERVICES,
H. L. MCMULLIN, *Chairman*.

AREA Bulletin 518, November 1954.

Report on Assignment 3

Federal and State Regulations Pertaining to Railway Sanitation,

Collaborating with Joint Committee on Railway Sanitation, AAR

H. W. Van Hovenberg (chairman, subcommittee), J. M. Bates, B. W. DeGeer, C. J. Freseman, R. S. Glynn, H. E. Graham, F. E. Gunning, S. H. Hailey, T. L. Hendrix, Jr., A. W. Johnson, G. E. Martin, G. F. Metzdorf, D. C. Teal, J. E. Wiggins, Jr.

This is a progress report, presented as information.

Your committee summarizes for this year the activities of the Joint Committee on Railway Sanitation, AAR, composed of representatives of the Engineering and Mechanical Divisions; the Medical and Surgical Section, Operating–Transportation Division; the U. S. Public Health Service; and the Department of National Health and Welfare of Canada.

The Joint Committee has continued through its special subcommittee to supervise the activities of AAR Sanitation Research and Development located at the AAR Research Center in Chicago, and has made recommendations for its maintenance and budget in 1955. Under the director and assistant director of this unit studies have been progressed principally with respect to phases of railroad sanitation bearing on potable water and water hydrants, waste disposal, food service, industrial cleaning chemicals, governmental regulations pertaining to railway sanitation, dining car refrigeration, and food handlers training programs for dining department personnel, along with visits to many AAR Member Roads to establish contact with officers who have been designated as responsible for sanitation matters within their respective organizations.

The Joint Committee has also continued to serve as liaison with the U. S. Public Health Service on aspects of sanitation related to railroad operations.

Your representatives on the Joint Committee are T. L. Hendrix, Jr., J. E. Wiggins, Jr., and H. W. Van Hovenberg, the last named serving also as the engineering representative on the special subcommittee.

Report on Assignment 5

New Developments in Water Conditioning for Diesel Locomotive Cooling Systems

Collaborating with Mechanical Division, AAR

M. A. Hanson (chairman, subcommittee), I. C. Brown, R. E. Coughlan, B. W. DeGeer, J. J. Dwyer, F. E. Gunning, E. C. Harris, T. W. Hislop, Jr., H. M. Hoffmeister, C. O. Johnson, H. M. Schudlich, R. M. Stimmel, A. G. Tompkins, J. H. Upham, J. E. Wiggins, Jr., E. L. E. Zahm.

Borate–nitrite type diesel cooling system inhibitors are being used rather extensively. A recent survey indicated that approximately half the railroads are now using the borate–nitrite type inhibitors. The results obtained using the borate–nitrite type inhibitors have been widely divergent, varying from excellent to completely unsatisfactory.

One moderately large railroad has used a borate–nitrite type inhibitor for approximately 1½ years. The raw water supplies are of a generally good quality. Most of the water supplies are pre-softened with zeolite softeners, followed by mechanical proportioning of the corrosion inhibitor. The concentration of inhibitors in the locomotives is periodically tested by laboratory personnel. The results accomplished are reported to be excellent on all models of locomotives owned. This is the only railroad reporting unqualified satisfactory results on models of locomotives known to be difficult to inhibit against corrosion.

Another relatively large railroad with less favorable raw water supplies, and with less favorable control and proportioning equipment, experienced such extensive corrosion in cooling systems that the use of borate–nitrite inhibitor was discontinued, and the use of alkaline chromate inhibitors was resumed. Alkaline chromate inhibitors had been previously used without experiencing any difficulty due to corrosion.

Various other railroads have obtained results intermediate between the two examples cited.

The borate–nitrite type inhibitors used have, in nearly all instances, been proprietary compounds. There have been changes from time to time in the formulation of these compounds which has increased the difficulties in arriving at a definite evaluation.

The results obtained to date are believed to justify the following conclusions:

1. Borate–nitrite type inhibitors are less effective at reduced concentrations than alkaline chromate inhibitors.
2. The concentration of borate–nitrite type inhibitors required for satisfactory inhibition is substantially double that required for alkaline chromates.
3. The borate–nitrite type inhibitors have such limited solubility that considerable difficulty is experienced in applying them to diesel engine cooling systems in the required concentrations.
4. The adoption of borate–nitrite inhibitors has been due to suspected skin irritations of employees handling alkaline chromates, rather than any lack of effectiveness of alkaline chromates as corrosion inhibitors.
5. No complaints have been received concerning borate–nitrite type inhibitors producing skin irritation.

Some question remains as to the effectiveness of borate–nitrite type inhibitors when used in waters containing substantial amounts of sodium chloride.

Some tests are underway using soluble oils as corrosion inhibitors. Another test is underway using sodium molybdate. There is insufficient field experience with either of these inhibitors to be able to make any certain evaluations.

This is a progress report, submitted as information.

Report on Assignment 6

Railway Waste Disposal

Collaborating with Joint Committee on Railway Sanitation, AAR

T. A. Tennyson, Jr. (chairman, subcommittee), W. F. Arksey, J. M. Bates, A. J. Bellerson, M. R. Bost, C. J. Freseman, R. S. Glynn, F. E. Gunning, T. L. Hendrix, Jr., Theodore Morris, J. Y. Neal, E. R. Schlaf, H. M. Smith, J. E. Tiedt, J. W. Ussher, J. E. Wiggins, Jr.

This year your committee has made a review of the state and federal regulations pertaining to the disposal of industrial wastes as discussed in the various trade and technical magazines and by circulation of a questionnaire. Results of this activity indicate that all states now have water pollution control laws and organizations to enforce them, or operate in compliance with the Federal Water Pollution Control Act (Public Law 845—80th Congress). In addition, most of the major river basins and coastal areas are covered by interstate agreements concerning the control of pollution.

State, federal and the interstate regulations are of the type discussed in your committee's report published in the Proceedings, Vol. 51, 1950, and our present survey indicates no basic changes since that time. This survey also indicates that the railroads have no real waste disposal problems unless it is, perhaps, to continue the efficient operation of waste oil separation facilities which some railroads have had to install. Some limits currently prescribed for oil in individual situations have been 10, 15 and 20 parts per million. The laws generally do not set arbitrary limits on specific waste materials but forbid discharge which "shall cause or contribute to pollution of waters of the state." An example is given by the definition of "unpolluted water or waste" established by Sanitation District No. 1, Campbell and Kenton Counties, Kentucky, which states that this "shall mean any water or waste containing none of the following: free or emulsified grease or oil; acid or alkali; phenols or other substances imparting taste or odor in receiving waters; toxic or poisonous substances in suspension, colloidal state or solution; and noxious or odorous gases. It shall contain not more than 10,000 parts per million by weight of dissolved solids, of which not more than 2500 parts per million shall be as chloride, with permissible volume subject to review by the District; and not more than 10 parts per million each of suspended solids and B. O. D." Some of the regulations do mention pH limits, which usually range between 6.0 and 8.5, although pH as high as 10.6 has been permitted. A complete list of the regulatory agencies and organizations concerned with water pollution control in the United States can be obtained from Subcommittee VII of ASTM Committee D–19.

This report is presented as information.

Report on Assignment 7

Treatment of Water For Cooling Purposes

L. E. Talbot (chairman, subcommittee), R. A. Bardwell, I. C. Brown, George Clark, D. E. Drake, J. J. Dwyer, C. E. Fisher, H. E. Graham, M. A. Hanson, C. O. Johnson, W. C. King, J. J. Laudig, G. F. Metzdorf, J. P. Rodger, A. G. Tompkins, J. H. Upham, J. W. Ussher, C. L. Waterbury, E. L. E. Zahm.

This is a report of progress, presented as information.

The increased use of air conditioning, both in railroad rolling equipment and office buildings, and the increased use of internal combustion engines on railroads during the past few years, have introduced new problems in water treatment. This report outlines some of the problems being encountered and gives current methods for their solution.

A. TYPES OF COOLING SYSTEMS

There are three general types of cooling systems used in industry. These are as follows:

1. Once-Through

In the once-through system the water passes through the heat exchanger equipment, absorbs heat, and then discharges as waste. Where the plant is relatively small, or in large plants where the available water supply is unlimited, this type of system is preferred. It is economical to install and produces less difficulty from corrosion and deposits in the heat exchanger than the recirculating system. No evaporation or concentration of solids takes place because the cooling water passes through only once. However, in some areas of the country, the once-through systems are not practicable because of shortages and costs of water supplies.

2. Open-Recirculating

The open-recirculating systems are being installed more and more, using spray ponds or cooling towers to release the absorbed heat to the atmosphere by evaporating a portion of the cooling water. This system saves water, as the only losses are those caused by evaporation, wind and blowdown. Evaporation of the water results in the concentration of the dissolved and suspended solids present in the make-up water. Also, the spray pond or cooling tower introduces an aerating effect which increases the dissolved oxygen content and thereby encourages corrosion.

3. Double-Recirculating

Where the raw water is very limited in amount, or where it contains an excessively high concentration of solids, double-recirculating systems are installed. In such systems the primary water that absorbs heat from the plant equipment is kept in a closed cycle and is not exposed to the atmosphere. The warm water in the closed system is cooled by secondary recirculating water passing through a heat exchanger, the open-cycle water being cooled by a cooling tower or spray pond. A double-recirculating system avoids evaporation and concentration in the closed cycle. The amount of make-up water for the closed system is thereby negligible, and condensate or properly externally treated water may be employed.

B. TYPES OF SCALE

1. Calcium Carbonate

The type of scale most commonly encountered in any circulating water subjected to increase in temperature and/or increase in concentration is calcium carbonate, which results from the decomposition of calcium bicarbonate in accordance with the following reactions:

$$\text{Calcium Bicarbonate} + \text{Heat} = \text{Calcium Carbonate} + \text{Carbonic Acid}$$
$$Ca(HCO_3)_2 + \text{Heat} = CaCO_3 + H_2CO_3$$
$$\text{Carbonic Acid} + \text{Heat} = \text{Carbon Dioxide} + \text{Water}$$
$$H_2CO_3 + \text{Heat} = CO_2 + H_2O$$

2. Calcium Sulfate

Calcium sulfate scale is rarely encountered in air-conditioning systems, except with unusual make-up water characteristics, since the solubility of calcium sulfate is not usually exceeded in these systems. The solubility would be exceeded in some instances where waters of permanent type hardness are used, or where sulfuric acid is used to remove temporary hardness.

3. Iron Oxides and Hydroxides

A special case of scale formation from ferrous bicarbonate may be encountered in cooling water systems employing iron-bearing well waters in accordance with the following reactions:

$$\text{Ferrous Bicarbonate} = \text{Ferrous Carbonate} + \text{Carbon Dioxide} + \text{Water}$$
$$Fe(HCO_3)_2 = FeCO_3 + CO_2 + H_2O$$
$$\text{Ferrous Carbonate} + \text{Oxygen} = \text{Ferric Oxide} + \text{Carbon Dioxide}$$
$$4FeCO_3 + 3O_2 = 2Fe_2O_3 + 4CO_2$$

Iron oxide may also be formed because of corrosion in the cooling system; however, this will be discussed under a special heading.

4. Mud and Silica

The build up of mud and/or silica in the cooling system is usually due to the presence of suspended solids in the make-up water or dust and dirt contamination from the atmosphere. If possible, these solids should be removed by external methods, such as coagulation and filtration.

C. USE OF THE LANGELIER INDEX

Prediction of the tendency to deposit calcium carbonate scale is readily made by the use of Langelier's equation. Based on a knowledge of the calcium, alkalinity, and dissolved solids content of the water, together with the pH value and the temperature encountered, Langelier's equation permits determination of the pH of saturation. It is calculated by the following method:

1. Knowing the temperature and total dissolved solids, find constant from Fig. 1. Locate this point on Col. 1, Fig. 2.
2. Aline this point with known value of calcium hardness on Col. 3, marking the intersection on Col. 2 (Pivot Line).
3. Aline this point on Pivot Line with known alkalinity on Col. 5.
4. Read pH saturation (pH_s) from the intersection of above line with Col. 4.

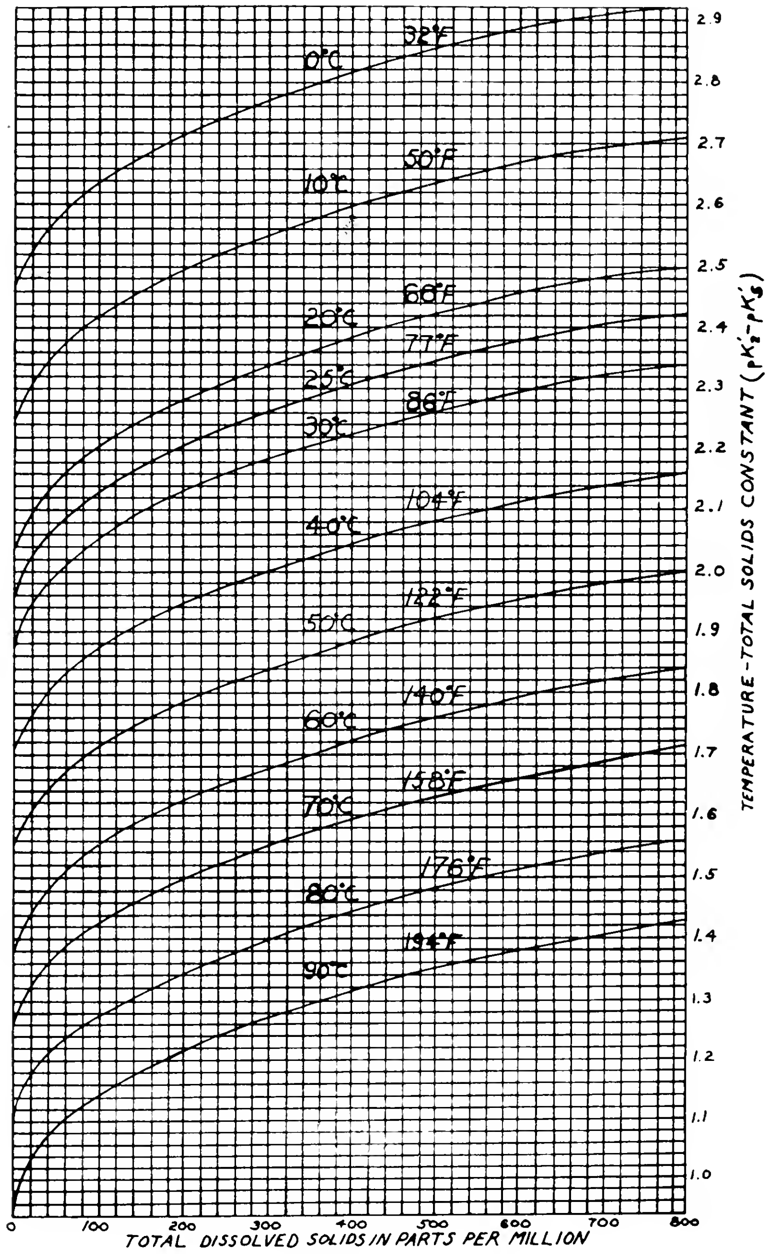
32°F
0°C
50°F
10°C
68°F
20°C
77°F
25°C
86°F
30°C
104°F
40°C
122°F
50°C
140°F
60°C
158°F
70°C
176°F
80°C
194°F
90°C
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
TEMPERATURE-TOTAL SOLIDS CONSTANT (pK'2-pK's)
0
100
200
300
400
500
600
700
800
TOTAL DISSOLVED SOLIDS IN PARTS PER MILLION

FIGURE 1

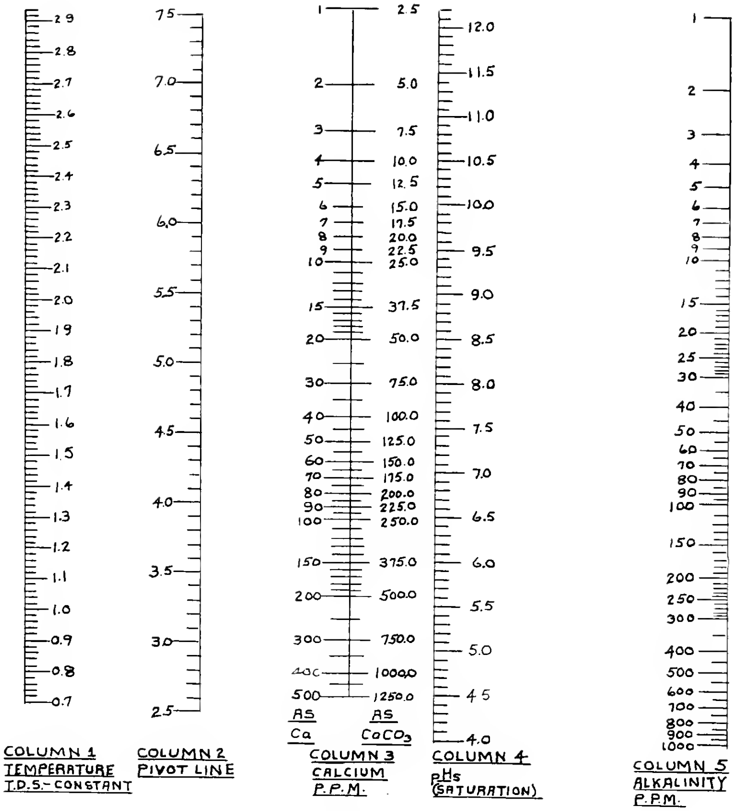

Figure-2

Nomogram for Determination of -pH Saturation

5. Saturation index is the actual pH minus pH saturation (pH_s).

If the actual pH exceeds the pH_s, the index will indicate incrusting tendencies; if the actual pH is lower than the pH_s, the water will be corrosive. Thus, a positive index indicates a tendency to deposit calcium carbonate scale, and a negative index indicates a tendency to dissolve scale, if present. A decrease in calcium hardness, alkalinity, temperature, or pH will lower the index, while a decrease in total dissolved solids will slightly increase the index.

The saturation index is a measure of directional tendency and driving force, but not of capacity, since it does not indicate how much calcium carbonate will deposit. For example, in zeolite softened water, where the effluent is very low in calcium, the index may be positive and high, but normally there will be no appreciable scale formed.

Limitations in the use of the Langelier index are due mainly to the effects of temperature. If, for example, the saturation index of a cooling system water (taken from the cooling tower) is —0.7, this index will change to —0.1 at approximately 200 deg F. This condition is due to the fact that the solubility of calcium carbonate decreases with temperature rise. The same conditions exist when the index at the lower temperature is in the positive range. In this case a rise in temperature would further increase the index. For this reason the use of sequestering agents is necessary in systems where a wide range of temperature exists.

Where adjustment of the index is necessary, lime or soda ash is used to raise the index, while sulfuric acid is normally applied to reduce it. If a water is properly treated and sufficiently inhibited, no trouble should be encountered with incrustation, provided that the saturation index is less than + 1.5.

D. METHODS OF TREATMENT FOR SCALE PREVENTION

1. Internal Treatment

a. *Once-Through Systems.* Prevention of scale formation in once-through systems usually depends on the addition of sequestering agents, such as polyphosphates and tannins, which have the property of preventing crystal growth and, therefore, scale deposits. For most waters having a positive Langelier Index, indicating scaling tendencies, the addition of 3 to 5 parts per million of a sequestering agent is usually sufficient to prevent deposition in once-through systems. This is because most natural waters do not have hardness of such magnitude that the polyphosphate organic treatments will not be effective; also, once-through cooling water is seldom held at elevated temperatures for long periods. However, if a water contains a large amount of scale-forming salts, and it is impossible for the treatment to work efficiently, it may be necessary to treat the water first by means of acid, lime or other means to reduce the hardness. The water should be treated to bring it within the effective range of the treatment recommended. The application of sulfuric acid to convert a part of the carbonate hardness to the sulfate form is the most convenient way to accomplish this result.

A special case of scale formation from ferrous bicarbonate may be encountered in once-through cooling systems employing iron-bearing well waters. This problem is handled either by the use of sequestering agents or by the use of an iron removal system. Because most of the iron deposits result from deposition of corrosion products, the treatment involved will be discussed under Corrosion Control.

b. *Recirculating Cooling Systems.* The problem of preventing scale formation in open recirculating systems is more difficult than in the once-through systems. The water in an open system is concentrated as a result of evaporation loss, which increases the mineral solids content. While calcium carbonate is the principal offender, it is also possible to encounter other scaling solids due to calcium and magnesium silicates and calcium sulfate. For this reason excessive concentrations in the water system must be avoided by blowdown procedures.

The type of treatment required to prevent scale in open systems is similar to that used in the once-through system, i.e., the use of sequestering agents, such as polyphosphates and tannins, which have the property of preventing crystal growth and, therefore, scale deposits.

2. External Treatment

a. *Cold Line Treatment.* Cold line treatment is widely used for the reduction of calcium hardness and an equivalent amount of alkalinity, thereby simultaneously lowering two of the factors contributing to the positive index. In this method hydrated lime is added to the water in a sedimentation tank; the water is allowed to clarify by sedimentation, and the effluent with this method is normally stable with respect to calcium carbonate saturation, indicating that the Langelier Index is only slightly positive at the elevated temperatures. However, increased temperatures plus the concentrating effect in the cooling system would result in an excssively positive index if no further treatment were applied. Therefore, acid is fed to the effluent for reduction of the pH and alkalinity.

Determination of the correct acid dosage is a matter of judgment, depending upon the water analysis and the number of concentrations taking place in the cooling system. In general, it is unwise to attempt to reduce alkalinity to less than 10 parts per million by acid. As an alternate, a polyphosphate may be used following the lime treatment, especially if the water is not heated to a high temperature.

With lime treatment a calculated index in the range of + 0.5 to + 1.0 at the highest temperature in the system is usually satisfactory.

b. *Zeolite Treatment.* Clear hard-water supplies may be treated for controlling scale by sodium zeolite softening all or a portion of the water. This type of treatment has the advantage of simplicity, since operation of the system requires limited chemical control. and the desired regeneration procedure can be fully automatic.

Complete zeolite softening should be used with discretion, for absence of scale may lead to corrosion. Also, where high raw water alkalinities are involved, the large amount of sodium bicarbonate contained in the sodium zeolite effluent will partially decompose to form sodium carbonate in the cooling water, which, in turn, give rise to a high pH water and may cause delignification of wooden tower structures. If it is desired to treat high alkaline waters by this method, sulfuric acid may be added to the effluent for the purpose of reducing the alkalinity. There are also other disadvantages where high alkaline water is allowed to concentrate in the cooling system, in that where appreciable loss of water by wind occurs, everything in the neighborhood of the cooling tower will be coated with a white deposit.

Partial zeolite softening with hard water by-pass, plus acid feeding if required for reduction of alkalinity, is a simple and flexible method of preventing excessive scaling. With this treatment, leaving appreciable residual hardness in the water provides protection against corrosion of ferrous heat exchange surfaces. As with the lime treatment, control is normally by use of the Langelier Index.

c. *Acid Treatment.* Another form of scale control consists of reduction of alkalinity by acid treatment. Calcium bicarbonate is converted to calcium sulfate in accordance with the following reaction:

Calcium Bicarbonate + Sulfuric Acid = Calcium Sulfate + Carbon Dioxide + Water

$$Ca(HCO_3)_2 + H_2SO_4 = CaSO_4 + 2CO_2 + 2H_2O$$

The carbonate alkalinity of the make-up water can be controlled within any desired limits by this method. Usually, acid is applied to adjust the "M" reading to between 2 and 3 grains per gal, or to maintain a pH range of from 6.0 to 7.0. When the pH is carried within this range, the Langelier Index will generally be negative and, therefore, calcium deposits will not be a serious problem. Exact control cannot be maintained with respect to index adjustments because of temperature differentials in the system and therefore, water treated by the acid method must also be further conditioned by the use of sequestering agents as previously discussed.

In the use of acid treatment, consideration must be given to calcium sulfate formations and concentrations in the system. While this material is quite soluble, it has solubility limitations and will form scale if the concentration exceeds approximately 2000 parts per million. The acid should be applied either to the return water inlet, the make-up line, or at the bottom of the cooling tower. Carbon dioxide gas is formed as a part of the acid reaction, but it will be partially removed by aeration in the tower if the acid required is applied as above. The amount of acid required is determined by the following calculations:

Acid (lb/100 gal) required = "M" reading — Residual "M" reading desired.

(Note—"M" reading is methyl orange alkalinity in grains per gallon in terms of calcium carbonate.)

It is usually advisable to feed sulfuric acid diluted to 5 to 10 percent strength, since better distribution and control of the dosage is obtained as compared with the use of concentrated acid.

d. *Blowdown Control.* Control of the number of cycles of concentration in the circulating water system is also important in order to prevent the development of excessive solids. In many cases the necessity for the use of acid treatment is avoided by maintaining lower cycles of concentration in the presence of sequestering agents.

The maximum allowable concentration will depend on the type of water in the system and the heat exchange temperatures encountered. For calcium carbonate type waters, the blowdown must be sufficient to keep the calcium carbonate concentration or the saturation index within ranges where the cooling water treatment will be effective. With waters containing high permanent hardness, the blow-down must be sufficient to prevent calcium sulfate from concentrating to the point where it exceeds its solubility—about 2000 parts per million. When sufficient sulfuric acid is used to reduce bicarbonate hardness, the calcium sulfate content of the cooling water is the limiting factor in controlling blowdown.

E. CORROSION FORMATIONS

1. Types

a. *General Attack* is a type in which the entire surface of the metal is corroded. Attacks of this type are generally due to a low pH or acid water, e.g., from sulfur gases or carbon dioxide. Because the attack is general in nature, failures are not common except under very severe conditions.

b. *Pitting* is a form of attack which is localized. Attacks of this nature result wholly from the presence of dissolved oxygen or some other localizing effect. In many cases pitting is accompanied by tuberculation; such corrosion may lead to objectionable deposits as well as metal failure.

c. *Micro-Biological Attack* is sometimes referred to as sulfate reducing bacteria. This type of corrosion generally occurs in the form of pits.

d. *Stray Current Electrolysis* is an attack in which the metal is eaten away, especially where the current leaves the system.

2. Types of Control

The manner in which an inhibitor functions is referred to as its control, but in general inhibitors act in a mixed manner, a combination of two or more of six types. They are as follows:

a. Anodic polarization.
b. Cathodic polarization.
c. Forming protective coatings.
d. Preventing harmful deposits.
e. Removal of corrosive constituents.
f. Adjusting the pH.

Soda ash and caustic soda are used widely to reduce the corrosiveness of various waters. These chemicals, and many others such as lime, alkaline phosphates, silicates, and borates, are employed to neutralize acidity. Neutralization can lessen corrosion but seldom eliminates it completely, unless other factors are brought into action. Where the water has a high negative saturation index and the sequestering agents will be of little or no benefit, it is recommended that the index be adjusted by using soda ash or caustic soda. An objection to soda ash is the danger of building too thick a carbonate layer on a heat transfer surface or clogging narrow passages. An advantage is low cost and the fact that it may be combined with many other treatments.

Sulfites have been reported to reduce some forms of corrosion. They are believed to function through removal of dissolved oxygen and are incompatible with oxidizing passivators. However, the reaction between commercial sulfite and oxygen is slow at cool water temperatures, and it is not practical for cooling water deaeration. Recently, catalyzed forms of sodium sulfite have been developed which react rapidly with oxygen at cool temperatures. Cost appears to be the main limitation of this treatment, since the sulfite requirement is about 10 parts per part of oxygen.

Molecularly dehydrated phosphates are an outstanding example of inhibitors which prevent harmful deposits. Through their softening and sequestering action they prevent deposition of substances which, in turn, might set up regions of different potentials. They also have cleaning actions which tend to remove deposits and surface incrustations. They help to keep the water clean in appearance by eliminating "red water"; however, some iron may remain in solution or in an invisible form. One of the best phosphates for this purpose is sodium hexametaphosphate. It may be used in one of two ways. The first is the threshold treatment which introduces 1 to 10 parts per million of phosphate. This has been found helpful in once-through systems, but metaphosphates tend to lose their sequestering properties on lapse of time by reverting to the orthophosphate, particularly when heated. The second method is to introduce a much larger amount in excess of that required to hold in solution all metal oxides. Intermediate proportions may cause precipitation of insoluble phosphates. In recirculating systems the lower pH values are advantageous, not only in changing the form of corrosive attack, but also in permitting the use of sufficient polyphosphate treatment to overcome the most severe corrosion problem without danger of the polyphosphate reverting to the orthophosphate form. This method has been found to be so satisfactory that adding acid to reduce the cooling water pH has become common practice. The best results have been obtained by maintaining the pH value of the water in the range of 6.0 to 7.0 and the polyphosphate concentration at from 70 to 80 parts per million at all times.

Borates have softening and sequestering properties, but less pronounced than phosphates. They have neutralizing properties, but a great deal more borate is required than soda ash. The advantage of using borates is that a large excess is harmless to certain metals which would be attacked by an overdose of more caustic compounds.

Sodium silicates function in somewhat the same manner as soda ash to neutralize acidity, but they have the additional property of forming siliceous compounds which may be deposited to form protective films. They also possess desirable cleaning and sequestering properties. Unlike other inhibitors, sodium silicates may be prepared in a slowly soluble form, making their use desirable in small units which are serviced at long intervals.

Chromate inhibits corrosion by forming a thin passivating film on the surface of the metal exposed to chromate solutions. This treatment is usually employed where ferrous metals must be kept entirely free from scale and, at the same time, be protected from corrosion. A concentration of about 300 to 500 parts per million of sodium chromate maintained in the circulating water forms a uniform thin barrier between the metal and the oxygen in the water. Unlike the phosphate treatment, the water used with this treatment should be slightly alkaline, and the concentration of dissolved salts should be less than 1000 parts per million. Because of their high cost chromium compounds are seldom used in once-through systems; if the make-up water is excessively high in recirculating systems, the cost of chromium compounds makes its use prohibitive in these systems also.

Sodium nitrite inhibits corrosion through anodic polarization in much the same manner as chromates. In protecting the metal the nitrite serves as an oxidant, being reduced to ammonia. Organic chromates, such as chrome glucosates, are true passivators, inhibiting corrosion through anodic polarization very much the same as inorganic chromates. They are used in recirculating water systems employing various types of cooling towers. Their effectiveness is roughly proportional to their hexavalent chromium content; but, since they are a little less reactive than inorganic chromates, they last a little longer, particularly when hot. These organic chromates tend to produce an adherent film which may be very dark in color, sometimes almost black. Because of the comparatively high cost of organic chromates, the inorganic chromates are of greater industrial importance.

Report on Assignment 8

Diesel Oil and Water Servicing Facilities

Collaborating with Mechanical Division, AAR

D. C. Teal (chairman, subcommittee), W. F. Arksey, G. A. Ausband, A. J. Bellerson, George Clark, D. E. Drake, C. E. Fisher, C. J. Freseman, F. E. Gunning, S. H. Hailey, T. L. Hendrix, Jr., A. W. Johnson, W. C. King, E. R. Schlaf, T. A. Tennyson, Jr., J. E. Tiedt.

This is a review and condensation of previous committee reports combined with new material to form a statement of recommended practice which is now submitted as information, with the recommendation that after further consideration, and with approval of collaborating organizations, it be published in the Manual. The report is divided into two parts, one dealing with the design and construction of fueling facilities, and the other with water supply for diesels.

SCOPE

The efficient operation of diesel power requires that fueling and watering facilities be available at engine terminals and at main line points for the servicing of through trains. Appropriate facilities must also be provided for diesel yard switchers. As shown in Fig. 1, these facilities generally consist of (1) fuel oil storage tanks, (2) fuel oil pumps, (3) distribution lines, (4) unloading facilities, (5) delivery to locomotives, (6) fire protection, and (7) diesel watering facilities.

A

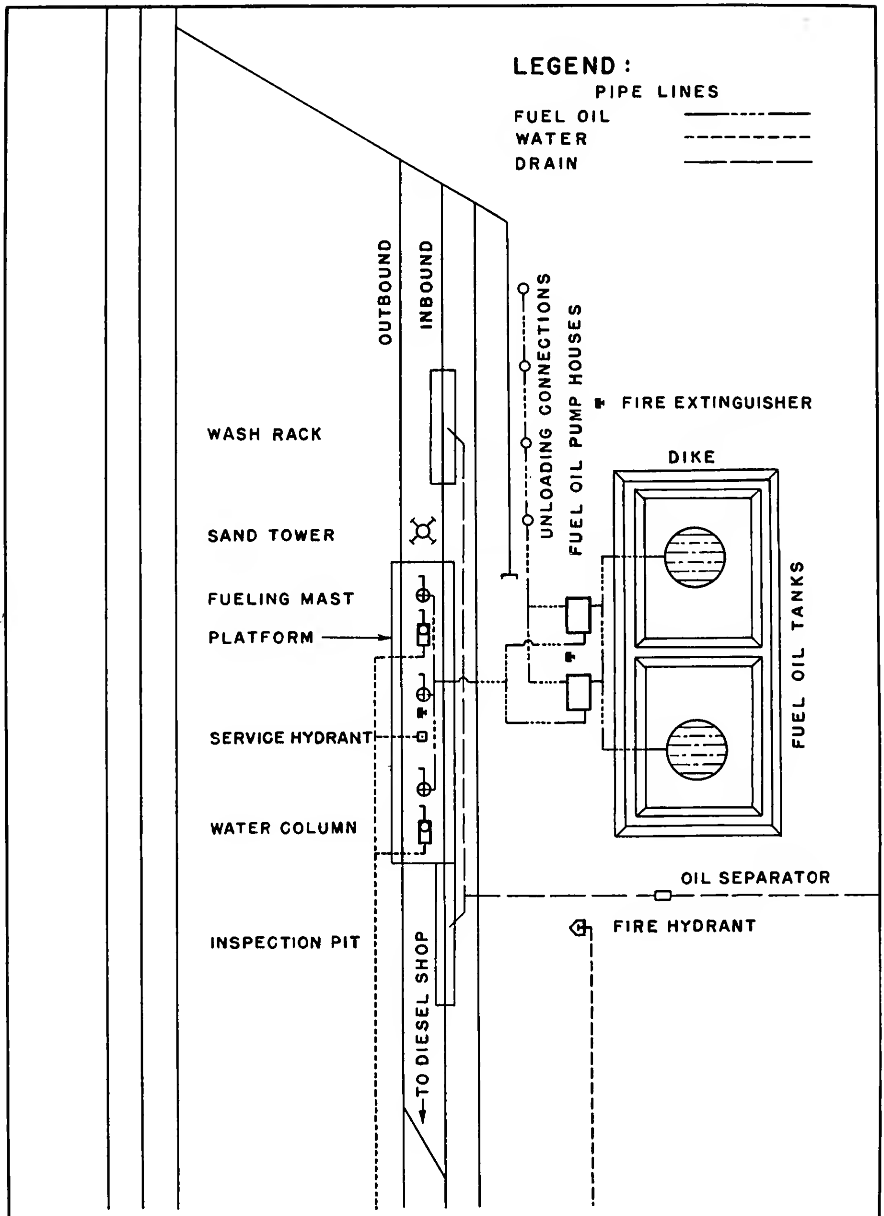

FIG. 1

DIESEL OIL AND WATER SERVICING FACILITIES

DIESEL FUELING FACILITIES

A. GENERAL CONSIDERATIONS

1. Characteristics of Diesel Fuel Oil

The design of facilities for handling diesel fuel oil must take into consideration fuel oil characteristics which will vary with the producer and as ordered by the individual railroad. Design should also recognize that economic pressure or a national emergency can adversely affect the quality of the fuel oil, especially with regard to viscosity, pour point, flash point and stability.

2. Compliance with Governing Laws Regarding Approval of Plans, Etc.

Major items that must be considered early in design work are listed below:

Submission of Plans. Most state fire codes require that plans for fuel oil storage or handling facilities be submitted to the state fire marshall for approval before construction is started.

Location of Storage Tanks. It is usually required that diesel fuel oil storage tanks be separated from each other by a distance equal to the diameter of the largest, and from the nearest property line by the same distance.

Dikes. Storage tanks should be surrounded by dikes, designed to contain the fuel oil to the immediate area in case of disaster.

Fire Protection Measures. See Sec. G. Fire Protection

B. FUEL OIL STORAGE FACILITIES

1. Storage Requirements

Adequate storage must be available for reserve in the event of interruption of delivery from normal sources of supply. Recommended practice is: For small stations—30 days' reserve; for large stations and system—60 days' supply.

2. Types and Sizes of Storage Tanks

Common and recommended practice is to use prefabricated cylindrical-type tanks for small stations and field erected standpipe-type tanks at large consumption points.

The size of prefabricated tanks is limited to 10 to 12 ft diameter and 40 to 50 ft long account of shipping restrictions.

Field erected standpipe-type tanks have been installed by railroads in sizes ranging from 26 ft in diameter by 25 ft high (100,000 gal), to 110 ft in diameter by 35 ft high (2,500,000 gal).

The decision of whether to install several smaller tanks instead of one large one should be based on total storage requirements, available space and relative costs. The operating advantages of a multiple-tank installation are obvious.

Where normal consumption at a station calls for a storage capacity of less than 100,000 gal, it will be economically advantageous to use one or more prefabricated tanks. For over 100,000 gal, use field erected standpipe-type tanks.

3. Design and Construction of Standpipe-Type Tanks

It is customary to contract for the fabrication and erection of standpipe-type storage facilities by outside steel companies on foundations furnished by the railway company. It is recommended that the tank itself be constructed in accordance with current AREA Specifications for Welded Steel Water and Oil Tanks, Part 3, this Chapter. Structurally supported roofs should be used on tanks over 30 ft in diameter. The American Petroleum Institute (API) standards may be used for appurtenances not covered by the AREA specifications.

4. Tank Appurtenances and Fixtures

Cylindrical storage tanks should be equipped with shell nozzle for inlet and outlet pipe connection; shell nozzle for drain connection; manhole on the top side; gaging hatch; level indicator; and a vent, the size of which should be in accordance with the American Petroleum Institute Venting Guide.

Standpipe-type storage tanks should have the following appurtenances: Shell nozzle for inlet and outlet pipe connection, shell nozzle for water drawoff connection, shell nozzle for air pipe (fire protection) connection, 24-in diameter shell manhole, 24-in diameter roof manhole, outside and inside ladders, level indicator, gaging hatch, water draw-off sump, and vent sized in accordance with the API venting guide mentioned above.

Recommended design features for tank appurtenances are as follows:

Location of Tank Outlet. Outlets should be located so that fuel oil will be drawn off 6 to 12 in above bottom of tank, thus allowing space for collection of water and sludge.

Water Draw-off Sump and Valve. Provide a small sump in bottom of standpipe-type tanks, with siphon pipe and a non-freeze valve in the shell to draw off accumulations of water.

Internal Check Valves. Provide an internal check (safety) valve in outlet pipe, which will automatically close in the event of fire, as and when required by state fire laws.

Level Indicators. These should be installed for the full height of the tank and be of a design that will permit accurate determination of the amount of oil in the tank.

Ladders. Vertical outside and inside ladders with 3/8-in by 2-in side rails and 3/4-in diameter rungs are recommended for use on standpipe-type tanks. Roof ladders are not ordinarily needed. The alternate to the vertical ladders, which would be a spiral stair arrangement with handrail, is expensive and not justifiable unless conditions require frequent climbing of the tank by operating personnel.

Vents. Mushroom, gooseneck or tee-type vents are equally satisfactory. They should be screened to prevent the entrance of birds. The use of flame arresters is not recommended as clogging often renders them inoperative and results in pumping difficulties.

5. Tank Foundations

Prefabricated Cylindrical Tanks. Common practice is to set these tanks horizontally on reinforced concrete saddle piers.

Standpipe-Type Tanks. The average tank of this design, full of oil, seldom weighs more than 2000 lb per sq ft of bearing surface, and in most cases can be installed on relatively inexpensive foundations. At locations where the bearing capacity of the soil is 3000 lb per sq ft or more, level the site and remove any soft top soil, then install gravel or medium size crushed stone over the foundation area to a height of at least 12 in above finshed grade and to a diameter slightly greater than that of the tank. This material should be confined at its perimeter by a circular reinforced concrete curb, which can also serve as support for the outer rim. The surface area between tank shell and curb, if any, should slope outwardly and be paved with concrete or asphalt. As a rust preventive measure a 3-in sand cushion, well mixed with a good grade of sulfur-free oil, should be spread over the area on which the bottom of the tank will rest.

Where the bearing capacity of the soil is less than 3000 lb per sq ft the foundation for tanks will require special design to meet local conditions.

6. Painting of Tanks

In preparation for painting, specifications should require that tank steel, after fabrication and before shipment, be immersed (pickled) in a hot dilute phosphoric acid bath designed to insure complete removal of mill scale and rust, then shop painted with a red lead or zinc chromate primer. After erection at the site the outside of the tank shell and roof should receive a second coat of the primer, followed by the finishing coat. The type of finishing coat should be compatible with the primer and its color in conformity with the railway company's standard. The majority of railroads in the United States have adopted aluminum or white paint for this purpose as it reflects, rather than absorbs, heat from the sun, and tends to keep the stored oil at a lower temperature in hot weather.

The underside of bottom plates should be given a bituminous coating prior to welding.

There is no need to paint the interior of a fuel oil tank.

A less expensive but not quite as satisfactory method of painting is to require that tank steel, after fabrication, be shipped without shop coat of paint. In this case, during erection, the steel should be thoroughly cleaned by wire brush or sand blast and then the outside should be allowed to weather for at least six months, after which the conventional two coats of primer and one finishing coat can be applied.

7. Dikes

Use earth construction where space is available and concrete where space is limited. Earth dikes are usually designed from 4 to 6 ft high, with a 3-ft crown and 1½ to 1 slope. The volume enclosed below top of dike should be at least 10 percent greater than the total capacity of the tank or tanks within the diked area. Tanks above 35,000-gal capacity should have individual dikes.

C. FUEL OIL PUMPING FACILITIES

1. Selection of Pump

Types. Electric motor-driven pumps of either the centrifugal or rotary type give satisfactory service and are recommended for railroad use. The centrifugal pump, with self-priming arrangement, may be used successfully where there is a flooded suction or very little suction lift, while the rotary is best suited to locations where appreciable suction lift is involved, such as when unloading from dome of a tank car. Rotary-type pumps are positive displacement and must be equipped with relief valve and by-pass to prevent the development of excessive pressures when outlets are closed.

Pump Motors. Calculations for power requirements must allow for friction losses through pipe, hose, and the various pieces of equipment such as filters, strainers, meters, etc., in addition to the static head against which the pump will have to work under maximum viscosity conditions.

Sizes. Freight and passenger diesels are equipped with fuel oil storage tanks that hold from 800 to 2400 gal, which are vented for a maximum delivery of around 300 gpm. The storage tanks of some of the small diesel switchers have a capacity of around 800 gal, and receive their fuel through an open end pipe by means of a nozzle valve similar to the way an automobile gasoline tank is filled. In consideration of the above, the following is recommended:

Use 200 to 300-gpm pumps at major engine terminals and main-line, through-train servicing points where fast fueling is required.

Use 50 to 100-gpm pumps for small switcher fueling points.

Number of Pumping Units. Each pump should be connected so that it can be used either for unolading from tank cars to storage, or for fueling diesels. One unit, so connected, is all that is needed at small consumption fueling points. Important stations, however, should always have two or more pump units.

2. Housing of Pumping Equipment

Pumping equipment should be protected against bad weather and to prevent meddling by unauthorized personnel. Prefabricated metal houses are recommended for this purpose. They should be of adequate size to accommodate pumps and all appurtenances.

In the case of duplicate pumping facilities, common practice, dictated by economy, is to install them together in the same house. Some railroads, however, prefer installation in separate houses on the basis that if one is subject to damage by fire, the other will still provide complete service.

3. Pumping Plant Appurtenances and Accessories

In addition to pumps, the proper handling of diesel fuel oil requires the use of certain accessories, such as fuel oil filters, strainers, meters, air eliminators, electrical facilities, etc., as outlined below:

Fuel Oil Filters. Diesel fuel oil must be filtered at least once, and some railroads make a practice of doing this twice before delivery to engines. The dual filtration can be accomplished by installing the filter equipment in the pump house on the discharge side of the pump so that the fuel oil will be filtered (1) as it is unloaded to storage, and (2) when it is pumped from storage to engines.

Practically all railroads use cartridge-type filters with removable elements. Their capacity should always be greater than the maximum pumping rate.

There are various kinds of filter cartridges, such as cellulose, cotton waste, pressed paper, and wood fiber.

The friction loss through a filter will be about 4 psi when cartridges are clean. These losses increase as elements become clogged. When the difference between inlet and outlet pressure, as shown on gages attached to filter, becomes excessive the dirty, cartridges must be replaced with new ones.

Strainers. A strainer with 30-mesh removable screen should be installed in the suction line next to or near the pump, as a precaution against intrusion by any sizeable foreign matter. Some railroads also provide a strainer just ahead of the fueling area meters.

Meters. One meter should be installed in the pump house on the discharge side of pump and one or more at each fueling point. Some railroads provide separate meters for each fueling outlet.

Meters should have a rated capacity somewhat greater than maximum pumping rate.

Rotary, positive-displacement-type meters are accurate, cause but little resistance to line flow, and are recommended for railway diesel fueling work. A wide variety of registers are available for use with the meter, including the continuous counter, good for 1,000,000 gal, and the reset dial, good for 10,000 gal. Also available is a recording printer dial for those who keep printed records of each oil delivery.

Air Eliminators. This equipment is commonly installed in pump houses on the discharge side of pumps, and ahead of filters and the meter. Its function is to release any entrapped air from the oil before it can enter and affect operation of the filters or the accuracy of the meter. A few railroads also make a practice of installing air eliminators just ahead of meters at the fueling outlets.

Electrical Facilities. The electrical work require for a fuel oil pumping plant consists mainly of power supply to building, circuit breakers, starters, and a start-stop control system for the pumps. The pump house and servicing areas should have electric lights.

The start-stop pump control system is an important part of the fueling system and should be made as automatic and fool-proof as possible. Recommended types of control are discussed under Sec. E. Unloading Facilities, and Sec. F. Delivery to Locomotives.

4. Pre-assembled Diesel Fueling Units

Recommended for fueling small diesel switchers at isolated locations are the pre-assembled fueling units that can be purchased in the open market. The assembly consists of a 50 to 100-gpm fuel oil pump connected to 50 ft or so of 1¼-in or larger hose with fueling nozzle valve at the end on a hand or motor-operated reel, a fuel oil meter, and in some cases a filter—all enclosed in a metal cabinet. The strainer and filter, if not already incorporated, can be installed on a common foundation outside the cabinet. This equipment can be used for unloading to storage as well as for fueling diesels.

D. FUEL OIL DISTRIBUTION LINES

1. General

Freezing is not a problem except for northern railroads, and for the others the fuel oil pipe lines can be installed either above or below ground. Pipes above ground must be supported at intervals and provision made for expansion. Underground piping must be protected against corrosion. In most cases, and under normal conditions, underground installation is preferred.

2. Pipe, Size, Kind; Type Joints

Pipe may be either steel or wrought iron. It should be sized to hold friction losses as low as practicable. Normally, this can be accomplished by using 3, 4 and 6-in pipe for 100, 200 and 300-gpm pumping rates, respectively. Flanged joints are preferred for valves and equipment located in pump houses or above ground. Line joints may be welded, flanged, screwed, or mechanical-joint type with bolts.

3. Depth of Bury for Underground Pipe and Use of Casing

There has been no general agreement on depth of bury, and the practice of individual railroads varies from 1 ft to 4 ft in the open, and 2 ft to 5 ft 6 in under tracks. The National Board of Fire Underwriters recommends 3-ft bury for open ground areas, and 4 ft 6 in under tracks (4 ft 6 in from bottom of ties to top of pipe). Piping under tracks should be installed in CI or steel pipe casing, the inside diameter of which is at least 2 in greater than the maximum outside diameter of the joints of the fuel oil pipe.

4. Protection Against Corrosion and Leakage

Leaks in underground fuel oil lines are hard to detect and can result in considerable loss. Recommended practice for underground work is to coat the pipe with an anti-corrosive preservative and to wrap it with tarred or plastic wrapping either before or during construction. Additional precautions are to back-fill around the pipe with sand or clay. Several railroads also advocate cathodic protection, using magnesium anodes.

5. Installation of Lines—Above Ground

Supports for above ground piping should be spaced 15 to 20 ft apart and may be constructed of rail or reinforced concrete. The total expansion–contraction due to changes in temperature is not too great and may be provided for by the conventional methods, such as loops, swing joints, and expansion joints.

E. UNLOADNG FACILITIES

1. General

Diesel fuel oil deliveries are usually made by tank cars.

Tank cars may be unloaded through the valve at the bottom of car or through the dome opening at the top. The chief advantage of the former method is that it affords a flooded suction for pump operation; its disadvantages are that it is practically impossible to connect a hose to the bottom valve mechanism without spilling oil. The overhead or dome unloading method is preferred by most railroads and is recommended for use where track centers permit.

2. Facilities for Bottom Unloading

Suction Connections. Recommend installation of one to seven suction line connections, depending on the number of cars to be handled, located alongside the unloading track at 40 to 50-ft intervals and at standard clearance. These connections should be size 3 or 4 in, depending on capacity of pump. When more than one connection is provided, each should terminate in a valve and hose connection nipple.

Hose. Provide 10 to 15 ft of wire-reinforced suction hose of oil-resistant material, such as neoprene, size 3 or 4 in, fitted at one end for attachment to suction inlet and at the other with a tank car coupling—at each suction inlet.

Hose Storage. An open metal trough for the hose to lay in, with a cover for the detached end of the hose, is recommended for this purpose.

3. Facilities for Dome Unloading

Dome unloading should be handled by means of overhead fixtures that take the place of the bottom unloading connection described above, and should consist essentially of a riser pipe from suction line with a counter-weighted double-swing joint at top, an extension arm that normally stands upright but which can be pulled down and across to dome of the car, and a lightweight non-ferrous metal drop pipe, minimum length 11 ft, swinging from end of the extension that can be lowered into the tank car. The riser pipe, size 3 or 4 in, should be the same height as tank cars (the average is 15 ft), and should be clamped to an I beam or equal, imbedded at the bottom in a concrete pedestal. There should be a gate valve in the riser and a bell strainer at the end of the drop pipe. The swing joints shall be ball bearing, with sealed-in lubricant and non-leaking ring seals.

4. Start-Stop Pump Control

Recommended practice is to provide a push-button start-stop switch at a central or convenient point to the loading area, with a green-red electric light indicator to furnish additional visual evidence of its position.

F. DELIVERY TO LOCOMOTIVES

1. General

Diesel locomotives are fueled as they enter or leave the diesel shops and at certain main-line stops. The fueling point outlets are installed in conjunction with other servicing facilities, such as for water and sand. Their location with respect to the other facilities depends on the type and number of diesel units regularly serviced.

It may also be necessary to provide special fueling facilities for diesel switchers in remote yards.

2. Fueling Masts

General. Final delivery of fuel oil to freight and passenger diesels is made via hose through a 2 or 2½-in opening in the side of each diesel unit. The overhead fueling mast with hose permanently attached is recommended for this service. The two recommended types are described below:

Crane Masts. These are made up of a riser pipe, size 3 in, reduced to 2 or 2½ in, 10 to 12 ft high, with a short horizontal extension at the top and a drop hose to make final connection. Swivel joints provide operating flexibility, and the working range is adjusted by the amount of hose used.

Vertical Swing Masts. Another design has the double-swing joint and vertical (pull-down) extension pipe at top of riser, similar to the overhead (dome) unloading connection previously described, except that the hose takes the place of the suction drop pipe. Although more expensive, this type mast provides greater working range with less hose, occupies less space, and has other operating advantages over the crane-type mast.

Appurtenances. General practice has been to install a shut-off valve in the riser pipe and a trigger-operated fueling nozzle at the end of the hose. The disadvantages of this arrangement are that the hose, when full of oil, is hard to handle, and that the oil confined between the two valves will expand with heat and rupture the hose or leak through the nozzle valve. The recommended alternate is to remove the nozzle valve from end, which leaves the hose drained and dry, except when in actual use. In this case the fuel oil delivery rate is controlled by the gate valve, and final quick shut off is made by an anti-surge type loading valve, both located in the riser.

Hose. The fueling hose should be 2 or 2½-in, depending on fueling rate, constructed of oil-resistant material and with fittings and special swivel coupling on the outlet end to match the inlet connection of the locomotive. Short hose, 10 to 12 ft in length, is preferred, but is not always compatible with the working range needed. If short enough, the hose can hang entirely suspended from overhead with bottom end secured to the mast. In case of longer hose, the part that would otherwise drag on the ground should have a metal trough to lay in, with protection against dust and provision for oil drippage at the end.

3. Pump Control

Recommended practice is to provide a push-button start-stop switch on each fueling mast, with a red light indicator to furnish additional visual evidence of its position. An alternate to the start-stop switch is a mercury-tube switch installed on the lever arm of the loading valve, which will automatically stop pump operation when the valve is closed.

G. FIRE PROTECTION

1. General

The inherent danger of fire around a diesel fueling station is due to the formation of flammable vapors resulting from the leakage or spillage of oil. Fire prevention measures must first of all curtail the leakage and wastage and avoid practices which allow vapors to collect or exist; secondly, minimize the possibilities of ignition by faulty equipment or from careless operation; and thirdly, provide adequate fire-fighting facilities. It is then up to management to inaugurate proper operating and maintenance practices to minimize the danger of fire, and at the same time to train the local firemen in the use of the fire-fighting facilities that have been provided.

2. Compliance with Governing Fire Laws

In the absence of local or state fire regulations, design and construction of fire-fighting facilities should be in general accord with the National Fire Protection Association Code.

3. Construction Measures to Prevent Oil Leakage and Spillage

Piping. Welded pipe joints are preferable for line pipe.

Valves. Lubricated plug valves are the least apt to leak and are recommended over gate valves.

Venting. The air eliminator in the pump house should be vented to the outside atmosphere.

Pressure Relief. Pressure relief valves should be piped back into the storage system and not discharged to atmosphere.

Pump Packing. Rotating pump shafts should be equipped with mechanical seals.

Lighting. Spillage can be curtailed by having adequate lighting for night fueling or unloading work, by having the attendant fuel only one unit at a time, and by not trying to fill the diesel engine tanks too full.

Paving of Fueling Areas. It is almost impossible to avoid some spillage at the fueling points and the oil-saturated premises will soon present a serious fire hazard unless adequate counter measures are taken. The recommended practice for important stations is to provide a concrete platform under the entire fueling area, with tracks supported on stub ties. The paving must be sloped to provide quick drainage into sumps or drains, which, in turn, should discharge through an oil separator. Another less expensive plan is to provide a concrete working platform with a gutter at the side of the track and install a sheet metal apron over the ends of the ties to direct spillage into the gutter.

The paving described above is not suited to Northern railroads because of the high maintenance expenditures required to keep the paved area free from ice and snow; nor is use of concrete paving economically justifiable at seldom-used fueling stations. Here, a working platform should be provided of sand or stone grits, which can be dug out and replaced as it becomes saturated with oil.

4. Construction Measures to Minimize Accidental Ignition

Electrical Work. All electrical work should be made vapor-proof and motors should be totally enclosed with a sealed terminal box. The wiring in the pump house should be in conduit. Circuit breakers and starters should be in dust-tight, explosion-proof cases. In this connection, many railroads install switches and starters in a panel box outside the pump house.

Welding. The welding procedures, especially for pipe repair work, should be in conformity with American Welding Society Standards.

Grounding. All fuel oil storage tanks should be grounded to permanent moisture as protection against lightning.

5. Fire Protection Facilities—Portable

Most fires have small beginnings that could easily be brought under control by the quick use of hand fire extinguishers.

Portable Equipment. Hand fire extinguishers should be located convenient to pump houses, unloading points and fueling areas. Dry power extinguishers are recommended for this purpose; they should be housed in cabinets painted red and otherwise identified as to their service.

6. Fire Protection Facilities—Permanent

Fuel oil fires can be extinguished by blanketing with foam, by rapid cooling with water fog, and, for a tank of fuel oil on fire, by agitation.

Fire Hydrants. A water supply system being available, fire hydrants, complete with accessories, should be installed convenient to all major fueling station operations, namely, unloading, storage, pumping and fueling. They should be carefully located so that in case of a major fire they will not be in an untenable locality. A single fire hydrant with two outlets and sufficient hose is minimum under ideal conditions. In many cases storage tanks will be located some distance from the other facilities and more than one hydrant will be required. Their outlets should be adaptable for use by the municipal fire department, if any.

Fire Hose Houses. It is customary to provide weather protection for fire hose and other fire-fighting equipment by installing small frame buildings over the hydrant which allow hose and nozzle to remain connected and racked, ready for instant use. These buildings should be painted red and otherwise identified as to service.

Fog and Foam Nozzles. Deluge nozzles are not recommended for oil fires because the large water volume tends to spread the burning oil and the concentrated stream does not have the cooling effect needed for reducing vaporization. Fog nozzles should be used in their stead. Foam nozzles with pick up piping and portable foam generators should also be placed in each hose house so they can be substituted quickly for the fog nozzles in case it becomes necessary to lay a foam blanket on a stubborn ground fire.

Stationary Foam Generators. Where fuel tanks are large or otherwise located where a fire would be extremely disastrous, the use of a stationary foam generator must be considered. This should be housed in a heated building located at a distance from the danger area, and be of adequate size to contain all equipment and the liquid or powdered foam stabilizer supplies. The foam chemicals are injected into the water supply in this building, and the branches from the manifold which receives the foam-treated water are piped to the various hydrants. The tops of the oil storage tanks also can be equipped with a fixed sprinkler system supplied from the manifold. The nozzles used for this type of construction should be for a combination foam and water fog, so that the latter can be used in case of failure of the foam generator or should the foam stabilizer supply become exhausted.

Control of Fire in Fuel Oil Tanks by Agitation. Actual field tests indicate that a tank of diesel fuel oil on fire can be extinguished within minutes by injecting air into the bottom of the tank. The agitation or heaving effect as the air rises carries comparatively cool oil from the bottom area to the top and upsets the combination of vapors feeding the flames.

Results of tests made so far are described in National Fire Protection Association publications, including more specific data as to how much air should be injected and where best to apply it.

7. Fire Protection at Locations Removed From a Regular Water Supply

At such locations and, depending on the value of facilities to be protected, consideration should be given to a fire tank car of at least 10,000-gal capacity, equipped with gasoline engine-driven fire pump, a generator for flood lighting night fires, and other fire-fighting equipment. The discharge head of the fire pump should be sufficient to overcome friction in 300 to 500 ft of 2½-in fire hose, and with 50 psi excess head to furnish minimum pressure for the operation of fog nozzles. The use of foam and fog will increase the effectiveness of a fire car with its limited supply of water, and this type equipment should be incorporated. The foam generator can be a permanent part of the car, installed next to the pump. Adequate supplies of foam liquid or powder should be stored on the car.

Cabinets of ample size should also be provided for the storage of hose and other equipment, i.e., nozzles, wrenches, raincoats, boots, helmets, axes, etc. These should be inspected and checked at regular intervals for presence and condition of the equipment.

H. USE OF LOW-GRADE FUEL OILS

1. General

Several railroads have already adopted, and others are considering the use of, less expensive, lower grade fuel oils in diesels, made possible by first treating it with one or more so called "additives". These are formulated to the special characteristics of the oil purchased and are designed to improve its performance by increasing the cetane number, stabilize against the formation of sludge or wax in storage, and disperse any insoluble residue that may have formed prior to treatment into such small particle size that they will not clog filters or other restricted areas. At the same time these additives must provide protection against the extra corrosive and contaminating influences common to inferior quality fuel oils. Treatment with a pour point depressant may also allow the use of certain oils that otherwise could not be used.

Dosages for fuel oil additives range from 1 pt to 2 qt, and the cost of treatment from $3 to $9 per 1000 gal of fuel.

2. Special Facilities for Treatment and Storage

Practices regarding the treatment, handling and storage of the low-grade fuel oils are not yet fully developed. The original treatment method of dumping the proper amount of additive in each tank car as it is filled at the refinery has the advantage of allowing ample time for mixing and chemical reactions. An alternate and preferred method is to inject the additive into the suction side of the unloading system by means of a proportioning pump, which arrangement gives the railway better control of the treating process.

The handling and storage of low-grade diesel fuel oils may require special facilities to avoid winter operational difficulties, especially in the northern states, where even the regular railway diesel fuels require heating. A recent Committee 13 report on this subject may be found in the Proceedings, Vol. 54, 1953, page 443.

DIESEL WATERING FACILITIES

A. INTRODUCTION

1. General

The operation of diesel power requires the use of water in cooling systems and steam generators. Water for the cooling systems must be scale free and non-corrosive to cylinder liners and other internal surfaces. Likewise, failure to remove or sequester dissolved minerals in the steam generator feed water will lead to scale and sludge deposits in the steam tubes which may result in clogged or over-heated tubes. While it is true that the total amount of water used by diesels is comparatively small, proper conditioning of this water is fully as important as for steam locomotives.

2. Water Treatment

In some cases reasonably soft, clear (boiler feed) water is already available at the servicing points, which can be made suitable for diesels by giving it a finishing treatment with one type of compound for cooling water and another for steam generator feed water. At other locations the available supply may have appreciable hardness and/or other objectionable characteristics that must first be corrected, in which case, the use of demineralizing or zeolite softening equipment is recommended.

Considerable research is being done on water treatment for diesels and practices are not yet ready for standardization. Recent Committee 13 reports on this subject may be found in the Proceedings, Vol. 53, 1952, pages 253 and 272, Vol. 54, 1953, page 439, and Vol. 55, 1954, page 359.

B. DIESEL COOLING WATER

1. General

Diesel cooling systems are flushed and refilled at terminals when the water becomes dirty or oily, or when the system has to be drained for repairs. Make-up water is added between refillings as required by leakage or evaporation.

The amount of water required to fill a diesel locomotive cooling system varies from 40 to 300 gal for switcher units, and from 215 to 650 gal for road units.

2. Servicing Facilities

At Terminals. In addition to the treated water supply, the diesel shop facilities should have a water heater, one or more water outlets, and enough rubber hose to reach diesel cooling water inlets. The heater is needed to furnish 110 to 150 deg F water for flushing and refilling warm locomotives.

Terminal facilities should be designed to deliver cooling water to diesels at a 50-gpm rate, which can usually be achieved with 2-in piping and 1½-in hose.

For Wayside and Switcher Servicing Points. These locations need only a water connection and sufficient rubber hose to reach the cooling water inlets on the diesels. Post hydrants are preferred. The system should provide a delivery rate of 20 to 25 gpm to diesels, which can usually be achieved with 1½-in piping and 1-in hydrants.

C. STEAM GENERATOR WATER

1. General

The capacities of steam generator water tanks on passenger diesel units range from 800 to 2400 gal. About 35 gal of water per hour is required to heat one passenger car with outside temperature at 0 deg F. When steam is used to operate air conditioning and other cooling equipment, the demand in summer may be almost as great as in the winter. A passenger train of 15 cars may thus require 1500 to 1800 gal of steam generator water during a 3-hr run, and watering points must be located accordingly.

2. Delivery to Locomotives

Number and Location of Water Outlets. The final delivery of steam generator water to passenger diesels is made at the servicing points—via hose and through a 2½-in opening in the side of each diesel unit. The ideal arrangement would be to have a water outlet located opposite the water inlet of each diesel unit when the locomotive is spotted at the servicing area. This is not always possible as the spacing of the inlets of multi-unit locomotives ranges from 45 to 78 ft, and a compromise has to be worked out by using longer hose or installing additional outlets. The fixed outlets should be located 10 to 12 ft from the center of track in order to provide working space.

Delivery Rates and Size of Water Lines. In view of the short time allotted for watering through trains and for terminal servicing work, it is recommended that these watering facilities be capable of delivering water to diesels at a rate of 250 gpm or more. With normal water pressures and friction losses, a 4-in supply pipe will usually furnish the desired flow rate.

Types of Outlets. There are three kinds in general use, namely, water boxes, post hydrants, and crane-type water columns. Although local conditions sometimes require the use of the first two, the crane type has many operating advantages and its use is recommended whenever possible.

Water Boxes. Three-inch diesel water boxes are available that can be installed flush with a station platform. The hose is detached when not in actual use and is stored separate.

Post Hydrants. Post hydrants, if used, should be of adequate size.

Diesel Water Columns. This equipment is made by several manufacturers and consists essentially of a 2½ or 3-in riser pipe, 10 to 12 ft high, with self-draining valve in an underground pit, a swivel arrangement at the top of the riser, and a drop hose to make final connection to the diesels. The working range is adjusted by the amount of hose used.

Another design has a counterbalanced double-swing joint and vertical (pull down) extension pipe at the top of the riser which provides greater working range with less hose, occupies less space, and has other operating advantages over the regular crane column.

Hose. Recommended for this service is 2½-in oil-resistant rubber hose with suitable couplings, and a special fitting on the outlet end with which to make connection to the inlet on the diesel. This hose can hang suspended from overhead, with the bottom end secured to the riser pipe. In case longer hose is needed, extension pieces can be attached to the end of the hanging hose.

3. Paving of Servicing Area

Most diesel steam generator water tanks are filled by attaching hose to the inlet on the locomotive and letting the water run until it overflows. With one man servicing two or more units it is almost impossible to avoid spillage, amounting sometimes to hundreds of gallons. The dumping of this water will wash away the ballast unless protective measures are applied.

At locations where 10 or more locomotives are watered per day, recommended practice is to provide a concrete platform over the entire servicing area, with the tracks supported on stub ties. The paving must be sloped to provide quick drainage into sumps or drains. Also, as spilled fuel oil will be collected along with the water, the drainage system should discharge through an oil separator.

A less expensive plan is to provide a concrete working platform with a gutter at the side of the track and sheet metal apron over the ends of the ties to direct spillage into the gutter.

Report of Committee 9—Highways

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R. W. Middleton
F. T. Miller
H. G. Morgan
C. I. Hartsell, *Vice Chairman*,
T. C. Nordquist
R. E. Nottingham
G. P. Palmer (E)
R. J. Pierce
N. E. Smith
H. E. Snyder
D. A. Steel
B. M. Stephens
T. B. Thompson
R. R. Thurston
J. M. Trissal
T. M. Vanderstempel
V. R. Walling
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Progress report, including recommended revisions .... page 370

2. Design and specifications of open-grating type crossings.
   Brief progress statement, presented as information .... page 376

3. Merits of various types of highway–railway grade crossing protection, collaborating with Signal Section, AAR, and Highway Research Board.
   Progress in study, but no report.

4. Outline to guide highway departments and others in making applications for easements, etc.
   Progress report, presented as information .... page 378

5. Standard stop sign for use by crossing watchmen, collaborating with the AAR Committee on Grade Crossing Protection.
   Progress in study, but no report.

7. Sight distance at highway–railway grade crossings.
   Progress report, offered as information .... page 380

10. The effect of highway improvement projects on railway properties, collaborating with the AAR Committee on Grade Crossing Elimination.
    Progress in study, but no report.

The Committee on Highways,
W. C. Pinschmidt, *Chairman*.

AREA Bulletin 518, November 1954.

Report on Assignment 1

Revision of Manual

C. I. Hartsell (chairman, subcommittee), Bernard Blum, Wm. J. Hedley, J. A. Jorlett, J. E. K. Krylow, H. G. Morgan, R. E. Nottingham, W. C. Pinschmidt, B. M. Stephens, T. B. Thompson.

Your committee recommends the following revisions to the Manual:

Page 9–2–2

Fig. 1—Painted Highway Crossing Sign, 6 Ft 50° Type.

Delete and substitute new Fig. 1—Highway Crossing Sign, Painted—6-Ft, 50-Deg Type, presented herewith. The new drawing provides additional information not presently contained in Fig. 1, Page 9–2–2, and the notes conform to succeeding drawings.

Page 9–2–3

Fig. 2—Highway Crossing Sign, 50° Reflector Type.

Delete and substitute new Fig. 2—Highway Crossing Sign, Reflector—6-Ft, 50-Deg Type, presented herewith. The new drawing provides additional information not contained in Fig. 2, Page 9–2–3, and eliminates the costly pinnacle, base and foundation. The text of the notes has been revised to conform with new Fig. 1.

Page 9–2–4

Fig. 3—Painted Highway Crossing Sign, 4 Ft, 90° Type.

Delete and substitute new Fig. 3—Highway Crossing Sign, Painted—4-Ft, 90-Deg Type, presented herewith. Additional information is provided both in the notes and on the drawing. The notes have been edited to conform to the notes on new Figs. 1 and 2.

Page 9–2–5

Fig. 4—Highway Crossing Sign, 90° Reflector Type for 4 to 8-in Pipe.

Delete and substitute new Fig. 4—Highway Crossing Sign, Reflector—4-Ft, 90–Deg Type, presented herewith. New Fig. 4 presents the sign and notes (as revised) in the same form, and with same additional information, as indicated on new Figs. 1, 2 and 3.

(Text continued on page 375)

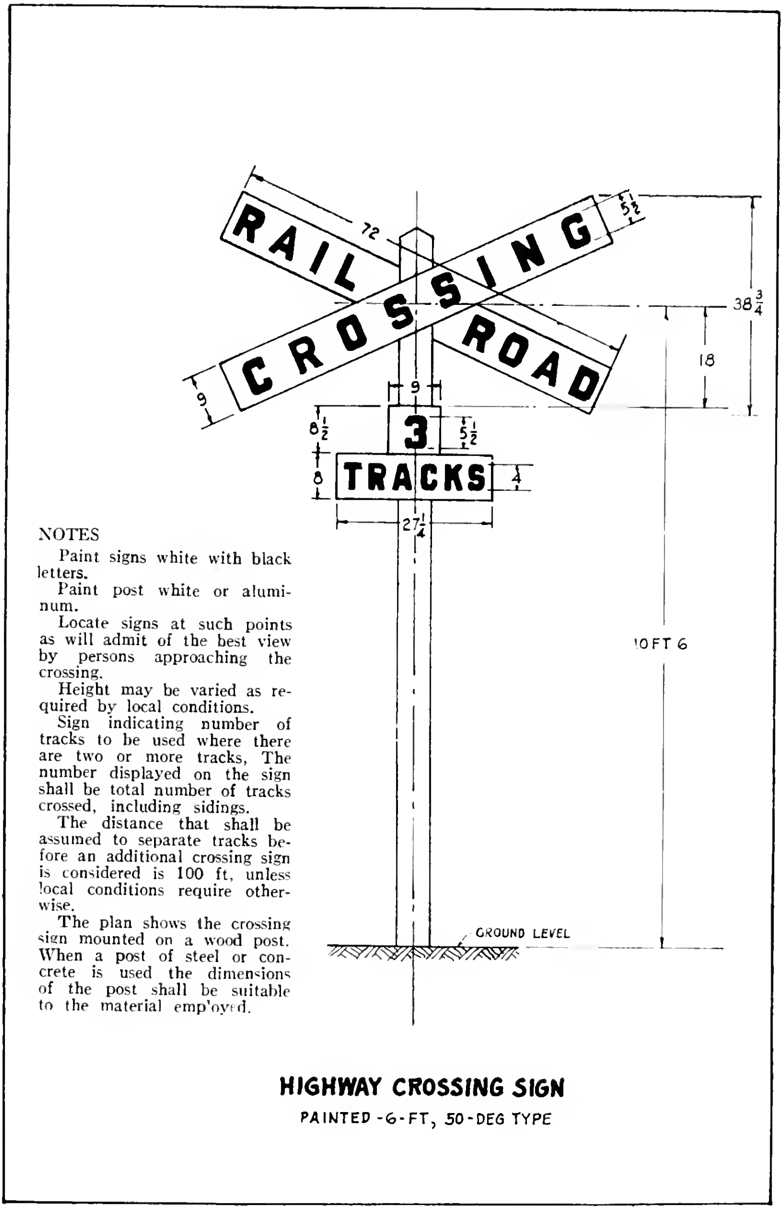
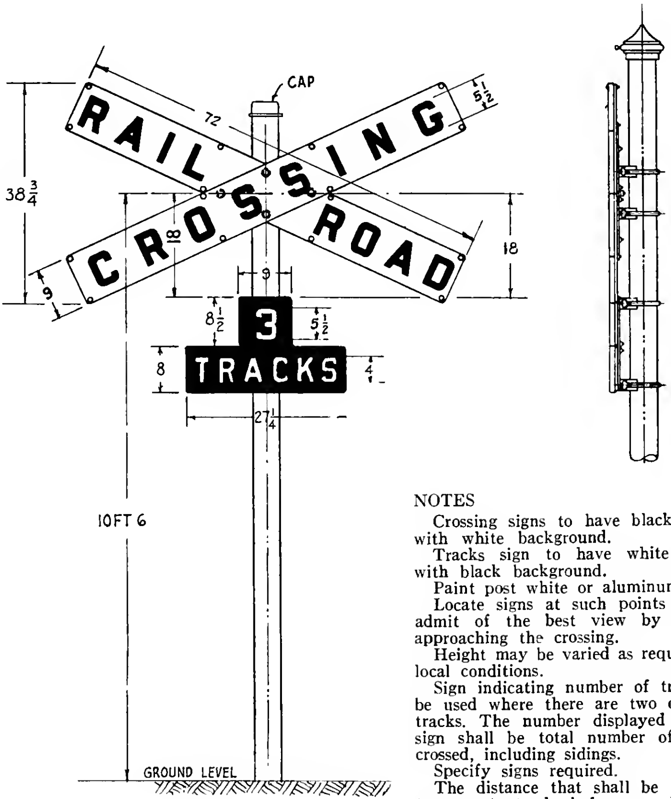

RAIL ROAD
CROSSING
72
5½
38¾
18
9
9
8½
3
5½
TRACKS
8
4
27¼
10 FT 6
GROUND LEVEL
NOTES
Paint signs white with black letters.
Paint post white or aluminum.
Locate signs at such points as will admit of the best view by persons approaching the crossing.
Height may be varied as required by local conditions.
Sign indicating number of tracks to be used where there are two or more tracks, The number displayed on the sign shall be total number of tracks crossed, including sidings.
The distance that shall be assumed to separate tracks before an additional crossing sign is considered is 100 ft, unless local conditions require otherwise.
The plan shows the crossing sign mounted on a wood post. When a post of steel or concrete is used the dimensions of the post shall be suitable to the material employed.
HIGHWAY CROSSING SIGN
PAINTED -6-FT, 50-DEG TYPE

Fig. 1.



NOTES

Crossing signs to have black letters with white background.

Tracks sign to have white letters with black background.

Paint post white or aluminum.

Locate signs at such points as will admit of the best view by persons approaching the crossing.

Height may be varied as required by local conditions.

Sign indicating number of tracks to be used where there are two or more tracks. The number displayed on the sign shall be total number of tracks crossed, including sidings.

Specify signs required.

The distance that shall be assumed to separate tracks before an additional crossing sign is considered is 100 ft. unless local conditions require otherwise.

The plan shows the crossing sign mounted on a pipe. It is permissible to place reflector signs on existing posts.

Details shown on Signal Section Drawing 1691.

HIGHWAY CROSSING SIGN

REFLECTOR - 6-FT, 50-DEG TYPE

Fig. 2.

NOTES

Paint signs white with black letters.

Paint post white or aluminum.

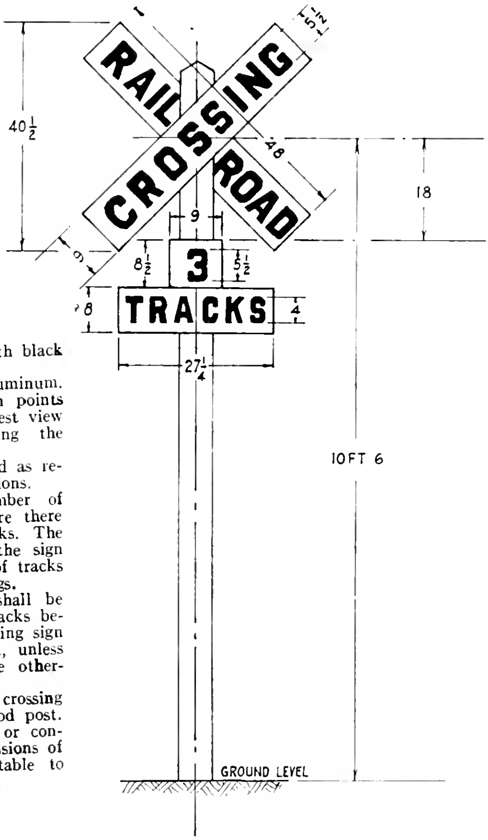
Locate signs at such points as will admit of the best view by persons approaching the crossing.

Height may be varied as required by local conditions.

Sign indicating number of tracks to be used where there are two or more tracks. The number displayed on the sign shall be total number of tracks crossed, including sidings.

The distance that shall be assumed to separate tracks before an additional crossing sign is considered is 100 ft, unless local conditions require otherwise.

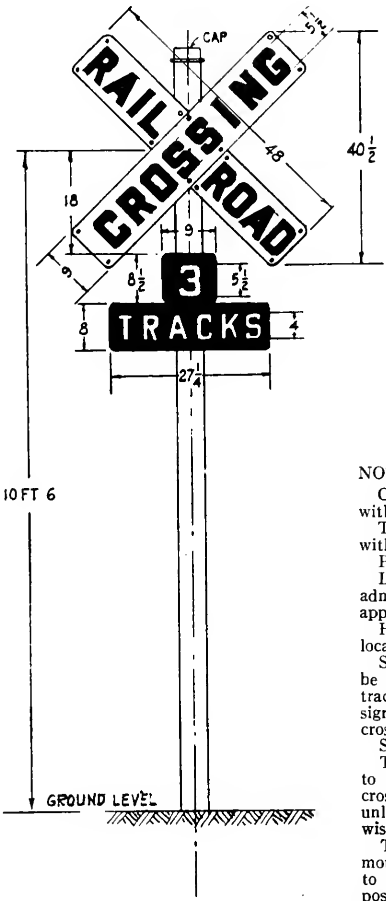
The plan shows the crossing sign mounted on a wood post. Where a post of steel or concrete is used the dimensions of the post shall be suitable to the material employed.

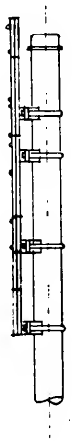


HIGHWAY CROSSING SIGN

PAINTED - 4-FT, 90-DEG TYPE

Fig. 3.





NOTES

Crossing signs to have black letters with white background.

Tracks sign to have white letters with black background.

Paint post white or aluminum.

Locate signs at such points as will admit of the best view by persons approaching the crossing.

Height may be varied as required by local conditions.

Sign indicating number of tracks to be used where there are two or more tracks. The number displayed on the sign shall be total number of tracks crossed, including sidings.

Specify signs required.

The distance that shall be assumed to separate tracks before an additional crossing sign is considered is 100 ft, unless local conditions require otherwise.

The plan shows the crossing sign mounted on a pipe. It is permissible to place reflector signs on existing posts.

Details shown on Signal Section Drawing 1722.

HIGHWAY CROSSING SIGN

REFLECTOR – 4 FT, 90-DEG TYPE

Fig. 4.

Page 9–3–1

RECOMMENDED USE OF HIGHWAY–RAILWAY GRADE CROSSING SIGNALS

Delete the chart and substitute revised chart, same title, presented herewith. The revised chart recommends the usage of additional signals under various crossing situations and has been expanded to include a recommendation as to where the "No Right Turn" and "No Left Turn" signals are to be used. It also shows the new Manual page numbers recommended for the drawing and requisites for "No Right Turn" and "No Left Turn" signals.

RECOMMENDED USE OF HIGHWAY–RAILWAY GRADE CROSSING SIGNALS

Crossing Situation	*Signal Recommended*	*AREA Manual Reference Pages*
At crossings where an indication of the approach of a train or the presence of a train or cars on the crossing is desired. At single-track crossings.	Flashing-light signal, as shown on pages 9–3–8 or 9–3–9, located as shown on pages 9–3–4 to 9–3–7, incl., or	9–3–2 to 9–3–9, incl.
	Wig-wag signal, as shown on pages 9–3–10 or 9–3–11, located as shown on pages 9–3–4 to 9–3–6, incl.	9–3–2 to 9–3–6, incl. 9–3–10 and 9–3–11, incl.
At multiple-track crossings.	Same as for single-track crossings, or	9–3–2 to 9–3–11, incl.
	Automatic crossing gate and signal, as shown on pages 9–4–4 or 9–4–5, located as shown on pages 9–3–4 to 9–3–7, incl.	9–4–1 to 9–4–5, incl. 9–3–4 to 9–3–7, incl.
Where street or roadway is very wide or where side of the road installations are likely to be obscured.	Cantilever flashing-light signal, as shown on pages 9–3–12 or 9–3–13.	9–3–12 and 9–3–13.
Where a street or roadway adjacent to and approximately paralleling a railroad intersects another street or roadway that crosses the railroad and the crossing is protected with highway grade crossing signals or gates.	"NO RIGHT TURN" or "NO LEFT TURN" Signal, as shown on page 9–3–15.	9–3–14 and 9–3–15.

Page 9–M–13

REQUISITES FOR "NO RIGHT TURN" OR "NO LEFT TURN" SIGNALS

Reapprove these requisites and insert as page 9–3–14 in order to keep all signal plans and requisites together for ready reference.

Page 9–M–14

Fig. 1—"No Right Turn" Or "No Left Turn" Signal–Assembly.

Insert as new Fig. 11, as revised, on page 9–3–15, in order to keep all signal plans together. The notes on the new drawing have been changed to conform to new Figs. 1, 2, 3 and 4 on pages 9–2–2 to 9–2–5, incl. Additional information has been included for clarification of the drawing. New Fig 11 is presented on page 377.

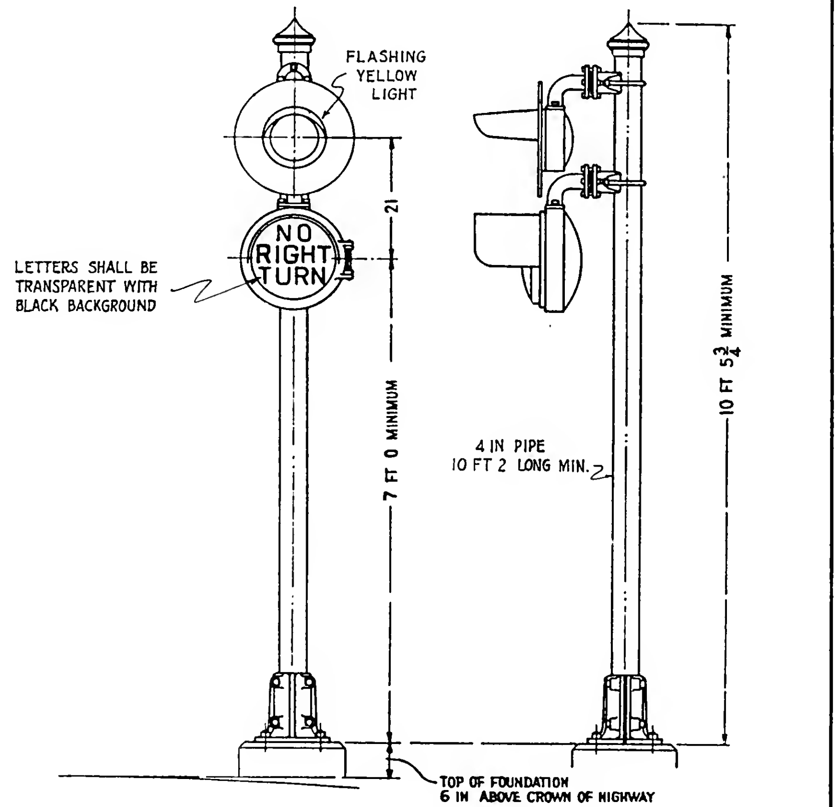
Report on Assignment 2

Design and Specifications for Open-Grating Type Crossings

R. E. Nottingham (chairman, subcommittee), H. D. Blake, Raymond Dejaiffe, L. W. Green, R. W. Harrison, J. T. Hoelzer, W. H. Huffman, P. L. Koehler, T. C. Nordquist, R. J. Pierce, W. C. Pinschmidt, V. R. Walling.

Your committee has continued its study of open-grating type crossings in order to determine the service life to be expected and to evaluate claims regarding performance.

Upon the recommendation of the committee, the Board Committee on Outline of Work has changed the wording of the assignment to "Merits and economics of metal grating-type crossings", and the committee will continue its study on this basis.



"NO RIGHT TURN" OR "NO LEFT TURN" SIGNAL

Fig. 11.

Report on Assignment 4

Outline to Guide Highway Departments and Others in Making Applications for Easements, etc.

E. R. Englert (chairman, subcommittee), H. D. Blake, C. O. Bryant, C. M. Carnahan, R. B. Carrington, Jr., M. H. Corbyn, W. R. Dunn, Jr., P. W. Elmore, R. W. Middleton, G. P. Palmer, W. C. Pinschmidt, D. A. Steel, V. R. Walling.

Railways are frequently requested to grant easements for highways, streets and other roadways. To assist the applicant in submitting sufficient information to enable a railway to review the request and to draw up an easement with minimum correspondence and delay, your committee submits the following outline of procedure. The outline is submitted as information; however, the committee plans to present it for publication in the Manual in 1956 and invites comments and criticism from the membership.

EASEMENT APPLICATIONS

(Highways–Streets–Roadways)

A. PURPOSE

This outline is for the guidance of highway personnel and others in making application for highway, street or roadway easements on railway property. Before an easement is granted, consideration must be given by several departments of the railway. By following this guide, field and office work, by both the applicant and railway, can be held to the minimum and the granting of the easement greatly expedited.

B. PROCEDURE

1. Plans

The applicant shall furnish the following drawings:

a. Plan view or situation map showing:

1. Railway property lines and improvements, such as tracks, buildings and pole lines that are likely to be involved.

2. Boundaries of the desired easement, with both ends tied in with bearings to the center-line of the nearest main track. The tie-in points are to be located by chainage along the center-line of the main track to the nearest permanent railway structure. The easement shall also be located in relation to local land survey ties where practicable.

3. Distance along the center-line of main track to the nearest railway mile post.

4. Proposed highway, street or roadway, together with secondary structures to be installed on the easement, incidental to the highway, street or roadway.

5. Existing and proposed drainage structures.

6. Edge of slopes.

7. Location of any construction or temporary easements.

b. Profiles of center-line of proposed highway, street or roadway, showing original ground line and proposed grade. Relative base-of-rail elevation of the main track at tie-in points of the easement shall be shown.

c. Details of present and proposed drainage shall be furnished when the run-off characteristics or storage are affected.

d. Cross sections of present ground line, showing proposed roadbed. The sections shall be carried to the center-line of nearest main track when the proposed roadbed is adjacent to the track roadbed. Where a crossing of railway tracks is involved, full details as to grade of road, tracks, pavement section and crown, superelevation, construction details, and procedures shall be furnished on a large-scale drawing.

e. A plat showing the easement shall be furnished on 8 by 10-in or 8½ by 14-in vellum or other material suitable for making reproductions.

2. Submission

a. The plans shall be submitted to the chief engineer of the railway, together with a formal letter signed by the applicant or a person duly authorized to negotiate such easement. The letter shall request the easement as well as explain the need for the easement.

b. The letter of submission shall include the name of the engineer, in charge of the work, to be contacted for a review of the proposal on the ground.

c. A copy of the application (letter and plans) shall be sent to the railway superintendent in charge of the territory where the easement is desired. If the railway superintendent is not known, the application shall be sent in duplicate to the chief engineer.

C. GENERAL

The location of highways, streets or other roadways must be made in accordance with Arts. 1, 2 and 3 of Location of Highways Parallel With Railways, Part M, Chapter 9, AREA Manual, where practicable. When the location cannot be made in accordance with Arts. 1, 2 and 3, then Art. 4 of the same document shall govern.

Report on Assignment 7

Sight Distance at Highway–Railway Grade Crossings

J. M. Trissal (chairman, subcommittee), H. D. Blake, C. O. Bryant, C. M. Carnahan, M. H. Corbyn, J. S. Felton, Marvin Gates, S. B. Gill, L. W. Green, J. T. Hoelzer, D. W. Hughes, P. L. Koehler, W. C. Pinschmidt, N. E. Smith, H. E. Snyder.

Your committee in reporting progress offers the following as information.

At highway–railway grade crossings where manual or automatic protection is not provided, sight distances may be provided which will allow the driver of an automobile to view railway traffic and to bring his vehicle to a stop before reaching the crossing.

Assuming conditions in which an automobile is proceeding at authorized speed on level, dry concrete pavement: In Fig. 1, "A" is the distance along the highway necessary to stop an automobile approaching the crossing at speed "V_1". "B" is the distance along the railway that a train traveling at speed "V_2" will traverse during the time that it takes an automobile traveling at authorized speed to stop clear of the track.

Stopping distance for alerted highway traffic traveling within the permissible speed will be provided when a train within "B" is seen from an automobile entering "A". The areas required for vision are indicated in Fig. 1 as "area of unobstructed vision".

Since "A" and "B" vary with speeds "V_1" and "V_2", respectively, Tables 1 and 2 have been prepared to show these distances over a range of speeds.

An automobile at a point within "A", continuing at speed "V_1", can pass over the crossing after observing a train, provided oncoming railway traffic had not entered "B" an instant before the automobile entered "A". However, an automobile attempting to halt from speed "V_1" in a distance less than "A" after observing a train within "B" traveling at speed "V_2" will be unsuccessful in either stopping before reaching the crossing or passing over the crossing in advance of oncoming railway traffic. This situation points to the fact that "areas of unobstructed vision" can only be effective in accident prevention where drivers are alert, cautious and respectful of crossing warning signs and posted speed restrictions. Active cooperation on the part of highway authorities is essential in the control of highway traffic and the establishment of areas of unobstructed vision at highway–railway grade crossings.

The committee recommends that the subject be continued.

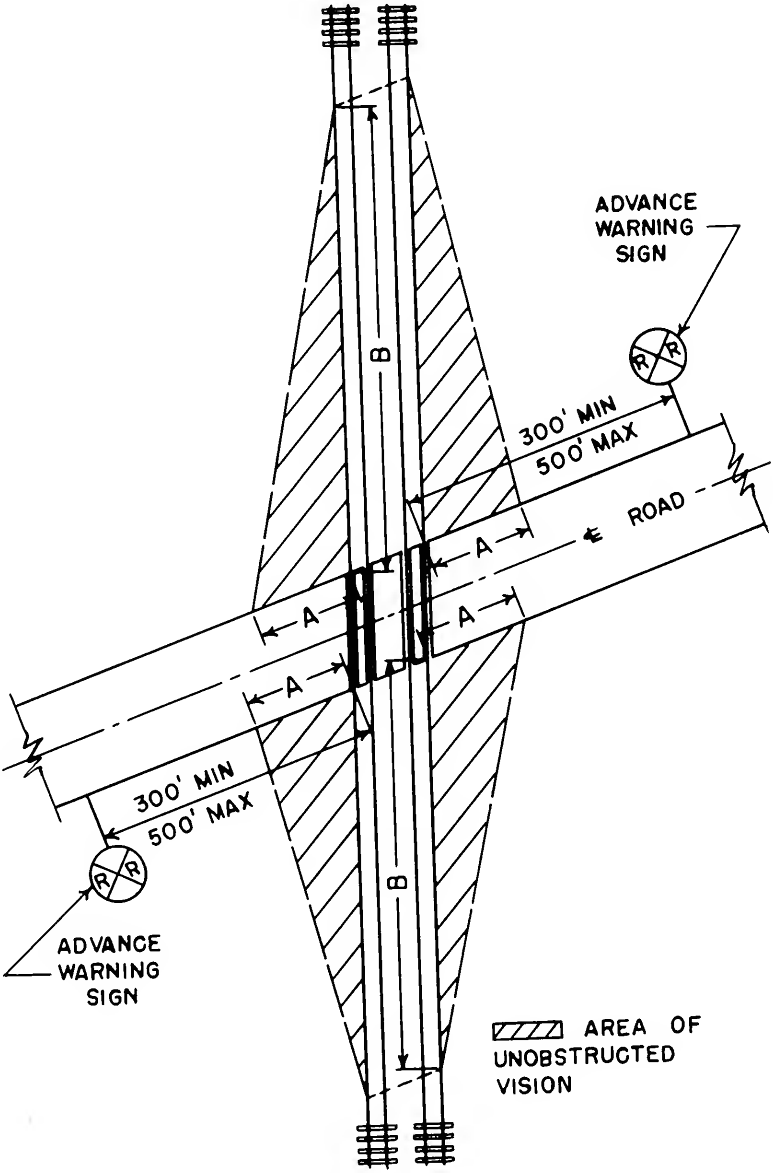

ADVANCE
WARNING
SIGN
R R
300' MIN
500' MAX
A
A
A
A
B
B
℄ ROAD
300' MIN
500' MAX
R R
ADVANCE
WARNING
SIGN
AREA OF
UNOBSTRUCTED
VISION

FIGURE 1

Table 1—Sight Distance "A" Along Highway (in feet)

Automobile Velocity "V_1" in MPH	*Braking Distance "D_1" in Feet**	*Driver Reaction Distance "D_2" in Feet***	*Sight Distance "A" (D_1+D_2) Along Highway in Feet*
10	5	11	16
20	20	22	42
30	45	33	78
40	80	44	124

*Median values of field test results conducted by five independent agencies.

**Driver reaction time assumed to be ¾ sec. Distance computed as product of reaction time and antuomobile velocity.

Note: No factor of safety is provided in braking distance to compensate for variations in coefficient of friction account unusual road surface conditions.

Table 2—Sight Distance "B" Along Railway (in feet)

Velocity of Railway Traffic "V_2" in MPH	*Velocity of Automobile "V_1" in MPH*			
	10	*20*	*30*	*40*
10	30	40	50	60
20	50	70	90	110
30	70	100	130	160
40	90	130	170	210
50	110	160	210	260
60	130	190	250	310
70	150	220	290	360
80	170	250	330	410
90	190	280	370	460
100	210	320	420	520

Note: Values of "B" are computed as product of automobile stopping time and velocity of railway traffic by following formula and rounded to next highest multiple of 10.

$$\text{"B"} = \left[V_2 \times \frac{5280}{3600} \right] \left[\frac{\text{Auto Braking Distance } D_1}{\frac{1}{2} V_1 \frac{5280}{3600}} + \tfrac{3}{4} \text{ Sec. Reaction Time} \right]$$

Report of Committee 20—Contract Forms

G. W. Patterson, *Chairman*
J. P. Aaron
G. H. Beasley
K. A. Begemann
H. F. Brockett
R. G. Brohaugh
R. F. Correll
A. B. Costic
G. K. Davis
G. K. French
C. L. Gatton
J. F. Halpin
J. R. Harris
E. M. Hastings, Jr.
C. B. Niehaus, *Secretary*
R. C. Heckel
W. E. Heimerdinger
C. J. Henry
H. W. Legro
J. S. Lillie (E)
L. W. Lindberg
D. F. Lyons
W. L. Mogle
O. K. Morgan (E)
B. F. Nauert
F. L. Nicholson (E)*
W. G. Nusz (E)
W. D. Kirkpatrick, *Vice Chairman*
R. O. Nutt
J. L. Perrier
E. E. Phipps
W. R. Swatosh
J. W. Wallenius
J. L. Way
W. E. Webb
D. J. White
I. V. Wiley
Clarence Young
H. L. Zouck

Committee

(E) Member Emeritus.
* Died May 24, 1954.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
Progress report, including recommended revisions .... page 384

2. Form of agreement covering subsurface rights to mine under railway carrier property.
Final report, submitted for adoption and printing in the Manual .... page 386

3. Form of agreement covering subsurface rights to mine under railway non-carrier property.
Study in progress, but no report.

4. Form of lease for development of oil and gas on railway lands.
Final report, submitting material for adoption and printing in the Manual . page 389

5. Insurance provisions recommended for various forms of agreements.
No report.

6. Form of agreement for turnpike or toll road crossing railway tracks and property.
Brief progress report .... page 390

The Committee on Contract Forms,
G. W. Patterson, *Chairman*.

AREA Bulletin 518, November 1954.

Report on Assignment 1

Revision of Manual

W. R. Swatosh (chairman, subcommittee), A. B. Costic, C. L. Gatton, J. R. Harris, E. M. Hastings, Jr., C. J. Henry, J. S. Lillie, B. F. Nauert, W. G. Nusz, G. W. Patterson, J. L. Way.

Your committee offers the following recommendations with respect to the Manual:

Pages 20–1–1 to 20–1–11, incl.

FORM OF CONSTRUCTION CONTRACT

The committee, in conformance with its assignment, reviewed during 1954 the Form of Construction Contract. Its review disclosed that some of the provisions of Sec. 11—Permits and Insurance, as now contained in the Manual form, should be revamped and that other changes and additions should be made in the text of said form in order that it be in harmony and on a current basis with other Manual agreements.

The committee recommends reapproval of the form with the following revisions and additions:

Page 20–1–2: Eliminate heading of Sec. 1—Terms of Employment, and insert "Independent Contractor".

Page 20–1–4: Eliminate clauses (d) and (e) of Sec. 11—Permits and Insurance, and insert the following revised clauses (d) and (e):

(d) Contractor's Public Liability insurance to cover bodily injuries, including death at any time resulting therefrom, with limits of $.................. one person and $.................. each accident, and damage to or destruction of property with limits of $.................. each accident and $.................. in the aggregate. This policy shall be endorsed to cover contractual liability as contained in the indemnity provisions of this agreement and the collapse and explosion hazards in addition to all other hazards, unless such endorsements are waived by the Chief Engineer.

(e) Contractor's Protective Public Liability insurance, if there are one or more subcontractors, in the same amounts for bodily injuries (including death resulting therefrom) and for property damage as required in (d) above.

Eliminate the last two paragraphs of above mentioned Sec. 11, and replace with the following:

Employees of the Company loaned or assigned to the Contractor, under the terms of this contract, for flagging and other protective service are to be considered employees of the Contractor for liability purpose.

Note.—Railroad Protective Public Liability and Property Damage insurance may be desirable for or in addition to above.

All policies must be written by reliable and well rated insurance companies acceptable to the Chief Engineer. Certified copies of policies, specified in clauses (d) and (e) shall be submitted to the Chief Engineer for approval before any work under this contract is commenced. When approved, they shall be retained by the Company, and the Contractor notified of their approval and authorized to enter on its property.

Said policies shall provide for notice to the Chief Engineer of the Company at least .... days in advance of cancellation.

Page 20–1–10: Add the following new Section:

39. Cancellation of Bond

If, ... months after such acceptance, it appears that said payrolls, material bills and outstanding indebtedness have been paid, and that the work is completed in accordance with the terms of this contract, the Chief Engineer shall authorize the cancellation of the bond given by the Contractor under this contract.

Pages 20–7–1 to 20–7–3, incl.

FORM OF AGREEMENT FOR THE USE OF RAILWAY PROPERTY BY HIGH-PRESSURE PIPE LINES, WITH SPECIAL REFERENCE TO PIPE LINES CARRYING INFLAMMABLE OILS AND GAS

At the suggestion of Secretary Howard and in collaboration with L. B. Yarbrough, chairman, Committee 4, Signal Section, your committee studied copy of said Signal Section report respecting cathodic protection of pipe lines crossing under railway tracks, bearing in mind as to the need for reviewing and revising Manual agreements in order that provisions for said protection be included therein.

The committee's study disclosed that the only form of agreement in the Manual needing revision was the Form of Agreement For Use of Railway Property by High Pressure Pipe Lines, With Special Reference To Pipe Lines Carrying Inflammable Oils and Gas.

Accordingly, your committee recommends reapproval of this form with the following revisions:

Page 20–7–1: In title of form change word "Inflammable" to "Flammable."

Page 20–7–2: Sec. 3—Construction and Maintenance, add the following three paragraphs as the second, third and fourth paragraphs of this Section.

The Licensee, upon the approval of plans and specifications by the Chief Engineer of the Company, may provide installation of cathodic protection at the time of initial construction or at any time subsequent thereto. The Licensee shall give the Chief Engineer .... days written notice before commencing any work in connection therewith. Said notice shall specify the period during which the installation of cathodic protection is to be made. The Licensee shall cooperate with the Chief Engineer in making any tests he requires of any installation or condition which, in his judgment, may have adverse affect on any of the Company's signal or traffic control systems, circuits, cables, wires, communication lines, or other facilities of the Company.

In the event the cathodic protection creates a hazard or in any way adversely affects the facilities of the Company, the Licensee shall forthwith abate or eliminate the created hazard to the entire satisfaction of the Chief Engineer.

All costs incurred by the installation, tests, or any necessary corrections thereafter, shall be borne by the Licensee.

Report on Assignment 2

Form of Agreement Covering Subsurface Rights to Mine Under Railway Carrier Property

I. V. Wiley (chairman, subcommittee), J. P. Aaron, G. K. French, R. C. Heckel, W. E. Heimerdinger, L. W. Lindberg, R. O. Nutt, J. L. Perrier, E. E. Phipps, H. L. Zouck.

Last year your committee presented, as information, a tentative draft of Form of Agreement Covering Subsurface Rights To Mine Under Railway Carrier Property (Proceedings, Vol. 55, 1954, pages 412 to 415, incl.), and requested comments and criticisms thereon. This form, with a number of minor revisions, is presented herewith, with the recommendation that it be adopted and published in the Manual.

FORM OF AGREEMENT COVERING SUBSURFACE RIGHTS TO MINE UNDER RAILWAY CARRIER PROPERTY

THIS AGREEMENT, made this .... day of ...., 19 ...., by and between ...., corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company and ...., hereinafter called the Licensee.

WITNESSETH:

WHEREAS, in order to reach adjoining lands the Licensee desires to construct, use and maintain tunnels or passageways under the tracks and right-of-way of the Railway Company situated in .... as shown on the plan designated as ...., dated ...., attached hereto and made a part hereof, and

WHEREAS, the Railway Company is agreeable to such construction, use and maintenance subject to conditions herein set forth;

NOW, THEREFORE, in consideration of the payment of $.............. in cash, the receipt of which is hereby acknowledged, and of the mutual covenants herein stipulated to be kept by the parties hereto, it is agreed as follows:

1. Grant

The Railway Company does hereby give and grant to the Licensee, insofar as the Railway Company has the power to do so, the right and privilege to enter within and under the right-of-way of the Railway Company and to construct, use and maintain tunnels or passageways in exact accordance with the plan, and no departure shall at any time be made therefrom except upon permission in writing granted by the Railway Company.

2. Cost

All materials and all work herein contemplated shall be furnished and performed by and at the sole cost and expense of the Licensee, and, without in any way affecting the obligations of the Licensee herein set forth, at such time and in such manner as shall be approved by the Railway Company.

3. Construction, Operation and Maintenance

The Licensee shall construct, operate and maintain the tunnels or passageways within and underlying the right-of-way of the Railway Company so as not to endanger, obstruct or interfere with its use for railway purposes or with the construction, operation and maintenance of all railway facilities which may now or hereafter be located on said right-of-way. (See Note 1).

The Licensee shall at all times maintain and repair the tunnels or passageways and all facilities used in connection therewith and shall in any event upon notice in writing from the Railway Company requiring it so to do, promptly maintain, repair or renew the whole or any part thereof; or the Railway Company for the purpose of protecting and safeguarding its property, traffic, employees or patrons, may at any time, with or without prior notice to the Licensee, provide materials for and perform any maintenance, repair or renewal which it may deem necessary, at the sole cost of the Licensee.

4. Right of Inspection

The duly authorized employees or agents of the Railway Company, shall have the right at all times to enter the tunnels or passageways for the purpose of inspecting the same, said right of entry to be afforded the Railway Company at any opening in the mine. The Licensee shall cooperate in making such inspections and furnish all things and do all acts necessary therefor.

5. No Openings

The Licensee shall not make any opening upon the surface of the right-of-way of the Railway Company.

6. Alterations to Railway Company Facilities

In the event the Railway Company shall be required or may desire at any time to change the grade or location of any of its tracks or facilities, or to remove, construct or add to any of its tracks or facilities upon the right-of-way of the Railway Company, the Licensee shall, without cost or expense to the Railway Company and within .... days after service of notice in writing requiring it so to do, make such adjustments or relocations in its facilities herein provided for as may in the opinion of the Railway Company be necessary and adequate.

7. Work by Railway Company

The Licensee shall reimburse the Railway Company for work performed by the Railway Company as described in Secs. 3 and 13 herein, promptly after bills have been rendered by the Railway Company for such work. Bills rendered by the Railway Company shall include the cost of labor, together with vacation allowance, Public Liability and Property Damage Insurance, Workmen's Compensation Insurance or Employers Liability Insurance and Federal Employers Liability Insurance, Unemployment Compensation Tax, payments pursuant to Social Security and Retirement laws, or similar laws, State and Federal, applicable to the work performed by the Railway Company, and .... percent on labor costs for supervision and administration. Material shall be billed at cost plus transportation and .... percent for handling, supervision and administration.

8. Taxes

The Licensee shall pay any and all taxes and assessments which may be levied against the Licensee and the Railway Company, or either of them, attributable to and growing out of the construction, operation and use of the tunnels, passageways and the facilities of the Licensee used in connection therewith.

9. Laws and Regulations

The Licensee shall at all times comply with, and conduct its operations under this agreement in conformity with the requirements of any Federal, State, or other public authority having jurisdiction in the premises.

10. Indemnification

The Licensee shall protect, indemnify and save harmless the Railway Company and any other corporation or person lawfully on its property from and against any and all loss or damage to property or injury to or death of persons, and all suits, claims, liabilities or demands in connection therewith, howsoever caused, resulting directly or indirectly from the construction, operation and maintenance of said tunnels or passageways.

11. Insurance

The Licensee shall at the Licensee's own expense carry insurance at all times in a company or companies approved by the Railway Company, covering the liability assumed under this agreement, with limits of not less than $............... for one person and $............... for one accident for personal injuries or death, and $............... for property damage for each accident with an aggregate limit of not less than $..............., and shall furnish the Railway Company true original counterparts of such policy or policies and have the Railway Company's written approval of said policies at least forty-eight hours before starting any work covered by this agreement Said policies shall provide for notice to the Railway Company at least .... days in advance of cancellation.

12. Extension of Operation

The privilege herein granted shall be fore the sole purpose of conducting mining operations by the Licensee, and the Licensee shall not use said tunnels or passageways for extension of operations beyond limits specified by this agreement, except by written consent of the Railway Company.

13. Term

This agreement and the authority and permission hereby granted to the Licensee shall continue for so long a time only as the Licensee shall continue to use the said tunnels or passageways for the purpose of conducting mining operations, and upon discontinuance of operations the Licensee shall fill said tunnels and passageways with such materials and in such manner as will be acceptable to the Railway Company. Upon refusal or failure of the Licensee so to do, the Railway Company may wreck and scrap or convert said tunnels or passageways and the facilities therein, fill in the said tunnels or passageways and restore its property at the sole cost and expense of the Licensee in accordance with Sec. 7.

In the event the Licensee shall refuse or fail to comply with the conditions and obligations placed or imposed upon the Licensee by this agreement, the Railway Company shall have the right, upon .... days notice in writing served or given to the Licensee, to cancel and terminate this agreement and to exclude said Licensee from the use of said tunnels or passageways provided for herein.

14. Assignment

This agreement shall not be assigned or in any manner transferred without the written consent of the Railway Company.

15. Successors

This agreement shall inure to the benefit of and be binding upon the parties hereto. their successors and assigns.

In Witness Whereof, the parties hereto have executed this agreement in ...., as of the day and year first above written.

Attest: .... Company
Secretary By ....

Attest: .... Licensee
Secretary By ....

Note 1.—Where material in seams, such as coal, talc, etc., is involved, it is suggested the following paragraph be inserted as part of Sec. 3:

> *The Licensee hereby further agrees for protection of railway tracks and right-of-way to leave at least .... percent of .... in place in uniform sized pillars beyond the limits of said right-of-way, within the limits of the Licensee's operations, for a minimum distance of .... ft measured at right angles from the center line of the nearest track of the Railway Company. It is expressly understood and agreed, however, that this requirement shall not release the Licensee from its obligation to provide adequate support for the Railway Company's tracks and right-of-way, nor from any liability in connection therewith.*

Note 2.—Bond may be provided if and as determined by the Railway Company.

Report on Assignment 4

Form of Lease for Development of Oil and Gas on Railway Lands

W. D. Kirkpatrick (chairman, subcommittee), G. H. Beasley, K. A. Begemann, H. W. Legro, W. L. Mogle, R. O. Nutt.

In 1952 and in 1954 your committee submitted as information, with requests for comments and criticism, a tentative Form of Lease for Development of Oil and Gas on Railway Lands (Proceedings, Vol. 53, 1952, pages 293 to 298, incl., and Vol. 55, 1954, pages 415 to 421, incl.). The committee now recommends the adoption and publication in the Manual of the form as it appeared in the Proceedings, Vol. 55, 1954, with the following addition and minor revisions:

Under Sec. 5—Operations, add the following paragraph:

(i) Upon termination of this lease or upon the abandonment of operations by the Lessee, the Lessee shall remove all buildings, derricks, structures, pipe lines, tanks or other facilities and fill all pits, sumps, etc., leaving the premises of the Railway Company in as good condition as when originally entered by Lessee, failing in which the Railway Company may perform such work as may be necessary and the Lessee hereby agrees to pay the cost thereof upon presentation of bill by the Railway Company.

Under Sec. 10—Indemnification, line 6, change "shall" to "will".

Eliminate word "Acknowledgments", which appears as last line of form.

Report on Assignment 6

Form of Agreement for Turnpike or Toll Road Crossing Railway Tracks and Property

J. W. Wallenius (chairman, subcommittee), H. F. Brockett, R. F. Correll, A. B. Costic, G. K. Davis, C. L. Gatton, J. F. Halpin, C. J. Henry, W. D. Kirkpatrick, H. W. Legro, J. S. Lillie, D. F. Lyons, W. L. Mogle, J. L. Perrier, W. R. Swatosh, W. E. Webb, Clarence Young.

Considerable work has been done in preparing a tentative form that has been presented to the committee for criticism and suggestions, but is not yet ready for formal report. The form will be revised and will be presented to the Association next year.

Report of Committee 25—Waterways and Harbors

Arthur Anderson, *Chairman*
G. H. Beasley
G. W. Becker
C. M. Bowman
H. G. Carter
A. F. Crowder
G. K. Davis
B. M. Dornblatt
W. H. Eckenbrine
N. E. Ekrem
Benjamin Elkind (E)
Oscar Fischer
R. L. Groover
C. J. Henry
B. M. Howard
H. F. Kimball
G. A. Knapp*
Shu-t'ien Li
G. W. Mahn, Jr.
F. B. Manning
S. L. Mapes
R. B. Midkiff
W. J. O'Connell
H. R. Peterson
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A. L. Sams, *Vice Chairman*
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C. R. Shaw
W. D. Simpson
F. R. Spofford
G. L. Staley
A. B. Stone
J. G. Sutherland
P. V. Thelander
J. L. Vogel**
V. R. Walling
G. A. Wolf

Committee

(E) Member Emeritus.
* Died October 13, 1954
** Died August 23, 1954

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Current policies and practices of the Corps of Engineers in dealing with navigation projects, collaborating with AAR Committee on Waterway Projects.

   Progress in study, but no report.

3. Bibliography relating to benefits and costs of inland waterway projects involving navigation.

   Progress report, presented as information .... page 392

The Committee on Waterways and Harbors,
Arthur Anderson, *Chairman*.

AREA Bulletin 518, November 1954

Report on Assignment 3

Bibliography Relating to Benefits and Costs of Inland Waterway Projects Involving Navigation

Shu-t'ien Li (chairman, subcommittee), C. M. Bowman, A. F. Crowder, G. K. Davis, W. H. Eckenbrine, N. E. Ekrem, B. M. Howard, H. F. Kimball, G. W. Mahn, Jr., R. B. Midkiff, W. J. O'Connell, J. G. Roney, J. G. Sutherland.

This is a report of progress, presented as information.

In its report last year your committee compiled a rather extensive bibliography of published material on the subject in question, which was presented in the Proceedings, Vol. 55, 1954, pages 459 and 460. Since that report the chairman of Subcommittee 3 has made an extensive search for appropriate additions to the bibliography and has submitted a suggested list of additions which will be considered by the committee in the year ahead. Meanwhile, the committee offers the following single addition to the previous bibliography:

"Cost Allocation," dated March 12, 1954, setting forth the manner in which costs of multiple-purpose projects shall be shared, as agreed upon and adopted by the Departments of the Interior and Army, and the Federal Power Commission.

Report of Committee 14—Yards and Terminals

J. N. Todd, *Chairman*
M. H. Aldrich
C. J. Astrue
F. E. Austerman
R. F. Beck
A. E. Biermann
W. O. Boessneck
E. G. Brisbin
W. S. Broome
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W. P. Buchanan
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H. W. Hem
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V. C. Kennedy
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E. K. Lawrence
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H. T. Roebuck
M. S. Rose
H. H. Russell
W. C. Sadler
W. H. Shoemaker
S. Shumate
R. A. Skooglun
J. C. Warren
G. R. Wurtele

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Classification yards, collaborating with Committee 16.
   No report.

3. Scales used in railway service.
   Specifications for four-section motor truck scales, submitted as information . page 394

4. Waterfront terminals.
   Report on ore piers, presented as information .... page 410

5. Study of the handling of LCL freight by conveyors.
   Final report, as information .... page 412

6. Facilities for loading and unloading highway semi-trailers on railroad cars.
   Progress report, as information .... page 416

7. Electronic devices used in yards and terminals, collaborating with Communications Section and Electrical Section, AAR.
   Final report, as information .... page 419

8. (a) Location and design of car repair tracks and facilities in relation to classification yards.

(b) Location and design of engine servicing tracks and facilities in relation to classification yards.

No report.

THE COMMITTEE ON YARDS AND TERMINALS,
J. N. TODD, *Chairman*.

AREA Bulletin 518, November 1954

Report on Assignment 3

Scales Used in Railway Service

C. L. Richard (chairman, subcommittee), E. G. Brisbin, N. C. L. Brown, W. P. Buchanan, G. H. Chabot, H. P. Clapp, B. F. Gilbert, H. W. Hem, V. C. Kennedy, E. K. Lawrence, C. F. Parvin, H. H. Russell, W. H. Shoemaker, J. N. Todd.

Your committee presents herewith, as information, specifications for the manufacture and installation of four-section motor truck scales, and recommends that the material be published in the Manual next year. Comments and criticisms are invited.

SPECIFICATIONS FOR THE MANUFACTURE AND INSTALLATION OF FOUR-SECTION MOTOR TRUCK SCALES

A. INTRODUCTION

These specifications define requirements for four-section motor truck scales of the knife-edge type with nominal capacities of 50 tons, or 100,000 lb, and with platform widths of 10 ft and platform lengths of 45, 50 or 60 ft. Basic application is to scales with type-registering weighbeams. For scales of the automatic–indicating or recording type, or with automatic–indicating or recording attachments, the specifications apply to all parts except those essential to the automatic features.

A four-section motor truck scale is one designed for weighing power-driven highway vehicles, including tractor–trailer combinations. It is constructed with one pair of main-lever load pivots supporting the weighbridge at each of four sections which are approximately equidistant.

AA. INFORMATION TO BE SUPPLIED BY THE PURCHASER

To assure definite proposals and acceptances of material when manufacturers or contractors are required to furnish scales, or are invited to offer bids to furnish scales conforming to the specifications herein, the information indicated in the schedule below must be supplied by the purchaser.

1. The nominal capacity of the scale and the size of the platform.

2. Whether plain or type-registering weighbeam is required.

3. These specifications contemplate the use of a concrete platform 6 in thick. If other material is to be used, state what it is. (See Sec. LL, Art. 8).

4. Whether the weighbridge is to be furnished completely fabricated.

5. Any special requirements for clearance between platform and weighbeam.

6. What installation service, if any, is to be furnished by the firm supplying the scale.

B. CAPACITY AND SIZES

Scale Capacity: The capacity of a scale is the heaviest load that can be applied to the platform without inducing stresses in any member in excess of those specified in Sec. C, the conditions of concentration of loading being those specified in Sec. CC.

Nominal Capacity: The nominal capacity of a scale is the largest weight indication obtainable by use of all the reading elements in combination, fractional elements totaling 2.5 percent or less of the remaining reading elements being neglected.

Size: The size of a scale is expressed by the dimensions of the platform surface. In rectangular platforms, the first dimension given is that of the platform edge nearest the weighbeam.

The nominal capacity of scales covered by these specifications shall be 50 tons, or 100,000 lb, and the size shall be (in feet) 45 by 10, 50 by 10, or 60 by 10.

As regards design, construction, workmanship and materials, these specifications apply only to scales having capacities and sizes within the limits given above. The design data (Secs. C and CC) do not hold for greater capacities, nor for scales with platform lengths greater than 60 ft.

(In the above statement of capacity and size the intent of the specifications is that minor variations from the nominal capacity and dimensions given for platform sizes are immaterial, and being otherwise in conformance with these specifications, the usually manufactured stock sizes are satisfactory.)

BB. PLANS

The purchaser shall, upon his request, be furnished written information showing the material of which scales proposed to be furnished are made, and if any material be not among those to which the safe stresses listed in Sec. C apply, the chemical and physical properties must be given in sufficient detail to permit confident judgment of the safe stresses or factors of safety used in design.

The purchaser shall be furnished assembly plans showing the location and size of open holes for field connections and all information necessary for the design and construction of the pit or all parts required and not furnished with the scale. (See also Sec. I). On request, the manufacturer shall furnish to the purchaser plans showing materials, stresses, and detailed dimensions for all scale parts.

C. WORKING STRESSES AND FORMULAS

1. General

In any scale loaded as required in Sec. CC, the unit stresses which follow shall not be exceeded. The stresses include a sufficient allowance for impact.

In designing cast iron members, the maximum allowable unit stress of any character shall be determined by the greatest thickness, exclusive of fillets, of the portion of the section carrying the stress being considered. In the main portion of a beam the thickness of the web or flange shall be used, whichever is the greater. The thickness of the flange shall be considered either as the average depth of the outstanding portion or the breadth of flange outside to outside, whichever is less.

In proportioning rivets, nominal diameters shall be used.

The effective bearing area of a pin, bolt or rivet is the diameter of the member multiplied by the thickness of the metal upon which the member bears.

In metal ⅜ in thick and over, half the depth of countersink shall be omitted in calculating bearing area.

2. High-Strength Alloys

For materials intended or represented to be "high-strength" alloys, unit working stresses other than those given in Table 1 may be used, provided these do not exceed one-third the unit stress at the yield point established according to the test routine followed or prescribed by the American Society for Testing Materials for parts of the same analysis, heat treatment and size, and provided further that the unit working stresses for any combination of gray iron and carbon steel exclusively shall not exceed those given in Table 1 for steel castings. The purchaser, if he requests, shall be furnished with sufficient data or test specimens to enable him to determine the physical properties of the particular "high-strength" material proposed to be furnished.

TABLE 1—WORKING STRESSES IN POUNDS PER SQUARE INCH

Material	*Transverse Bending*		*Direct Stress*		*Shear and Torsion*
	Tension	*Compression*	*Tension*	*Compression*	
Cast Iron (gray). Thickness of section *Inches*					
0.25	5,000	8,500	3,500	10,000	5,000
0.3	4,780	8,130	3,350	9,560	4,780
0.35	4,600	7,820	3,220	9,200	4,600
0.4	4,450	7,560	3,110	8,900	4,450
0.45	4,320	7,340	3,020	8,640	4,320
0.5	4,200	7,140	2,940	8,400	4,200
0.6	4,020	6,830	2,810	8,040	4,020
0.7	3,870	6,580	2,710	7,740	3,870
0.8	3,740	6,360	2,620	7,480	3,740
0.9	3,630	6,170	2,540	7,260	3,630
1.0	3,540	6,020	2,480	7,080	3,540
1.1	3,450	5,860	2,410	6,900	3,450
1.2	3,380	5,750	2,370	6,760	3,380
1.3	3,310	5,620	2,320	6,620	3,310
1.4	3,250	5,520	2,270	6,500	3,250
1.5	3,190	5,420	2,230	6,380	3,190
1.6	3,140	5,340	2,200	6,280	3,140
1.8	3,050	5,180	2,130	6,100	3,050
2.0	2,970	5,050	2,080	5,940	2,970
2.5	2,810	4,780	1,970	5,620	2,810
3.0	2,690	4,570	1,880	5,380	2,690
3.5	2,580	4,390	1,810	5,160	2,580
4.0	2,500	4,250	1,750	5,000	2,500
Steel castings	10,000	12,000	10,000	12,000	8,000
Pivots and bearings					
SAE 1095, hardened	24,000	24,000	24,000	24,000	----------
SAE 6195 or 52100 hardened	30,000	30,000	30,000	30,000	----------
Structural					
SAE 1010 to 1020	10,000	10,000	10,000	10,000	7,000

Stress in extreme fibers of pins	15,000
Shear in power-driven rivets and pins	7,500
Shear in turned bolts and hand-driven rivets	6,000
Bearing on pins	14,000
Bearing on power-driven rivets, milled stiffeners, and other parts in contact	15,000
Bearing on rocker pins	7,000
Bearing on turned bolts and hand-driven rivets	11,000

Minimum thickness of weighbridge members shall be ⅜ in.

3. Knife-Edge Bearing Stresses

The load per inch of knife-edge shall not exceed 5000 lb for high carbon steel (SAE 1095) or 6000 lb for special alloy pivot steel (SAE 6195 or 52100).

4. Concrete Bearing Stresses

The stress to be allowed for bearing on concrete shall not exceed 300 psi.

5. Projecting Pivots—Formula for Stresses

Where practicable, the pivots shall be supported their full length by integral parts of the lever. Where impracticable so to support the pivots, external bending moments shall be determined as follows:

Let M be the required bending moment in inch pounds.
L, the length in inches of the moment arm,
W, the total load in pounds on both ends of a pivot,
D, the length in inches of bearing in the loop,
T, the distance in inches between friction faces of the loop,
B, the width in inches of the boss, or the sustaining member enveloping the pivot.

Then

$$L = D/2 + (T-B) + \tfrac{1}{4}\text{ in}$$

and

$$M = WL/2$$

6. Floorbeams and Floor Slabs

When loads are, or may be, applied to the scale platform from any direction, the following principles of design applicable to floorbeams and floor slabs shall be used. If for any reason of design or installation, traffic over the scale is constrained to follow within definite limits a given direction, the floorbeam sections, and the flooring may be calculated to conform to the established traffic conditions.

7. Shears and End Reactions in Floorbeams

In calculating end shears and end reactions in transverse floorbeams, no lateral or longitudinal distribution of the vertical concentrated live loads shall be assumed.

8. Bending Moments in Floorbeams

In calculating bending moments, no transverse distribution of loads shall be applied. With the floor slab resting upon floorbeams and main girders the floorbeams shall be designed for the maximum wheel load that can be placed on a single floorbeam, with a single 27,000-lb axle or two 18,000-lb axles when all wheels are on the scale.

In calculating the load on a floorbeam from two 18,000-lb axles, assume the floor between the floorbeams to act as a simple beam.

9. Distribution of Wheel Loads on Concrete Slabs: Bending Moment

In calculating bending stresses due to wheel loads on concrete slabs, no distribution in the direction of the span of the slab shall be assumed. In the direction perpendicular to the span of the slab, the wheel load shall be considered as distributed uniformly over a width of slab which is termed the "effective width" and is obtained from the following formulas, in which

S is the span of the slab in feet,
W is the width of tire in feet (or the permissible wheel load in pounds, divided by 12,000),
D is the distance in feet from the center of the near support to the center of the wheel, and
E is the "effective width" in feet for one wheel.

Case 1—Main Reinforcement Parallel to Direction of Traffic

$E = 0.7S + W$, in which E shall have a maximum value of 7.0 ft.

When two wheels are so located on a transverse element of the slab that their effective widths overlap, the effective width of each wheel shall be $\frac{1}{2}(E + C)$, in which E is the value determined by the formula above and C is the distance between centers of wheels.

Case 2—Main Reinforcement Perpendicular to Direction of Traffic

$E = 0.7\ (2D + W)$.

For this case, the bending moment on a strip of slab 1 ft in width shall be determined by placing the wheel loads in the position to produce the maximum bending, assuming no distribution; determining the effective width for each wheel; and assuming the load of each wheel on the 1-ft strip to be the wheel load divided by its respective effective width.

The design assumption of Case 2 does not provide for the effect of loads near unsupported edges. Therefore, at locations where the continuity of the slab is broken, the edges of the slab shall be supported by diaphragms or other suitable means.

10. Shear in Slabs

Slabs designed for bending moment in accordance with the foregoing rules and for the wheel loads contemplated by these specifications may be considered adequate for shear without special reinforcement.

11. Placing of Reinforcement

The minimum clear distance between parallel bars shall be 1½ times the diameter of round bars, or 1½ times the diagonal of square bars. The maximum spacing shall be 2½ times the slab thickness. Bars parallel to the face of any member shall be imbedded a clear distance of not less than 1 in from the face.

12. Members Supporting Deck Overhang

In calculating bending moments, and shears and reactions in members supporting the flooring outside the main girders, no lateral or longitudinal distribution of the vertical live loads shall be assumed.

13. Bearing Pressures Under Foundations

The bearing areas of the foundation footings shall be such that the pressure under the footings will not exceed

For fine sand or clay	4,000 psi
For coarse sand and gravel or hard clay	6,000 psi.
For boulders or solid rock	20,000 psi.

If the soil has not a safe bearing capacity equal to that of fine sand or clay, its bearing capacity shall be increased by drainage, by adding a layer of gravel or broken stone, or by driving piles.

14. Platform Overturning Moments

When calculating moments tending to overturn or tip the platform, no distribution of vertical live loads shall be assumed.

CC. PARTICULARS OF LOADING

1. General

All parts of scales shall be proportioned for the following loads and forces:

(a) Dead load.
(b) Live load.
(c) Impact, or dynamic effect of live load.
(d) Lateral forces.
(e) Longitudinal forces.

2. Dead Load

(a) Unless provision is otherwise made in these specifications, the dead load shall be considered in the design of scales. The dead load shall be considered as the weight of all the parts of the scale structure supported by the main-lever load pivots and balanced out for zero weighbeam reading.

(b) The unit weights in Table 2 shall be used in computing the dead load.

TABLE 2—UNIT WEIGHTS OF MATERIAL FOR USE IN COMPUTING DEAD LOADS

Material	*Weight per Cubic Foot (Pounds)*
Steel—Use handbook values or	490
Cast iron	450
Timber, treated or untreated	60
Concrete, plain or reinforced	150

3. Live and Dead Loads

The live load shall be assumed to be a five-axled vehicle whose wheel gage, axle spacing and axle loadings are as shown in Table 3. For the general purpose of design, the vehicle shall be assumed to be positioned with its longitudinal axis between the weighbridge girders and parallel to the longitudinal center line of the scale, and one series of wheels in the vertical plane through the web of one weighbridge girder. For the section and main-lever reactions, one rear wheel shall be assumed over the center of a main load bearing. No lateral or longitudinal distribution of the wheel loads shall be assumed.

TABLE 3—SCHEDULE OF LIVE LOADS

Axle	*Axle Load (Pounds) (Wheels Spaced 72 In Apart, Center to Center)*	*Distance Center to Center Following Axle (Inches)*
1	8,000	168
2	18,000	40
3	18,000	100
4	18,000	40
5	18,000	--

The combined live and dead loads to be used in design of parts shall be as listed in Table 4 (see also Sec. CC, Art. 4).

TABLE 4

Platform Size (Feet)	*Weighbridge Section (Feet)*	*Main Lever Load (Pounds)*	*Section Load (Pounds)*	*Total Load on Lever (Pounds)*
45 x 10	15 x 10	29,500	49,900	123,200
50 x 10	16.7 x 10	32,600	55,300	128,600
60 x 10	20 x 10	38,400	65,400	139,800

Note 1.—The "main-lever load" is the greatest permissible combined live and dead load reaction at any main load pivot.

Note 2.—The "section" is the greatest permissible combined live and dead load reaction at the two main load pivots of the same section of the scale.

4. Impact

In the design of scales covered by these specifications, when stresses are used not greater than the "Working Stresses", Table 1, Sec. C, herein, no increase need be made to vertical live loads, or need any other allowance be considered to provide for the effects commonly included under the general term "Impact".

5. Lateral Forces

The platforms shall be designed for a lateral live load concentrated at the center of each span, equal to 20 percent of the capacity plus 100 lb per ft of span.

6. Longitudinal Forces

Provision shall be made for the effect of a longitudinal force of 10 percent of the capacity of the scale, acting in the plane of the platform and in a vertical plane through the longitudinal center line.

D. SCALE LEVERS

1. Limitation of Type

Truss rods designed as parts of a lever structure to support vertically applied loads will not be permitted.

2. Qualities of Castings

Cast pieces used for levers shall not be warped. They shall be clean, smooth, uniform and free from blisters, blowholes and shrinkage cracks.

3. Machined Ways for Nose Irons

Levers that are to be equipped with nose irons shall have those portions of the lever ends receiving them machined for the full distance over which the nose irons are to move.

4. Nose Iron Guides

The guides for all nose irons shall be such that when one is moved for the purpose of adjustment, the pivot will be held parallel to its original position.

5. Leveling Lugs

Each lever shall be provided with leveling lugs for longitudinal alinement. Each pair of lugs shall be spaced 11 in. The leveling surfaces of each pair of lugs shall be finished to a common plane parallel to the plane through the knife edges of the end pivots.

6. Marking of Levers

Figures denoting the ratio of each lever shall be cast or otherwise permanently marked on the lever.

DD. PIVOTS AND BEARING STEELS

1. Material

The material used for pivots and bearing steels in scales covered by these specifications shall be either—

(a) Special alloy pivot steel (SAE 6195 or 52100), hardened to not less than 58 Rockwell C, or

(b) Carbon steel (SAE 1095), hardened to not less than 60 Rockwell C.

2. Design

All pivots shall be so designed and manufactured that the included angle of the sides forming the knife-edge will not exceed 90 deg, and the offset of the knife-edge as referred to the center line of the pivot will not exceed 10 percent of the width of the pivot for machined-in pivots, and 15 percent of the width of the pivot for cast-in pivots.

3. Fastening

All pivots shall be firmly fastened in position without swaging or calking.

4. Continuous Contact

All pivots shall be so mounted as to obtain equal and continuous contact of the knife-edges with their respective bearings for the full length of the parts designed to be in contact. In loop bearings the knife-edges shall project slightly beyond the bearings in the loops.

5. Position

In any lever, the pivots shall be so mounted that—

(a) Each knife-edge will be maintained in a horizontal plane under any load within the capacity of the scale.

(b) A plane bisecting the angle of a knife-edge will be perpendicular to the plane through the knife-edges of the end pivots.

(c) The actual distance between the end knife-edges of any lever will not differ from the nominal distance by more than $\frac{1}{64}$ in per ft.

(d) The knife-edges in any lever will be parallel.

6. Support for Projecting Pivots

The reinforcing on the levers to support projecting pivots shall be tapered off to prevent accumulation of dirt next to the pivots and to provide proper clearances.

7. Design of Bearings

Bearing steels and the parts supporting or containing them shall be so applied to the mechanism that permissible movement of the platform will not displace the line of contact between any bearing and the opposing pivot.

8. Interchangeability of Bearing Steels

All bearing steels of the same nominal dimensions or parts identification shall be interchangeable or mounted in interchangeable bearing blocks. The interchangeable part shall be securely mounted in the part containing it.

9. Finish of Bearing Steels

The bearing surfaces shall be brought to a smooth, true and accurate finish to insure continuity of contact with opposing pivots.

E. NOSE IRONS

1. Design

Nose irons shall be so constructed that—

(a) They will be positioned by means of adjusting screws of standard size and thread.

(b) They will be retained in position by means of screws or bolts of standard size and thread.

(c) The surfaces of nose irons intended to be in slidable contact with the levers will be true, so as to secure an accurate fit in or on the levers. Such surfaces shall be machined.

(d) When adjustments are made, the knife-edge will be held parallel to its normal position.

2. Screws and Bolts

Adjusting and retaining screws and bolts shall be made of a corrosion-resistant material.

3. Retaining Device

A device for retaining each nose iron in position shall be provided and shall be so designed and constructed that—

(a) It will be independent of the means provided for adjustment.
(b) It will not cause indentations in the lever.
(c) Loads applied to the scale will not cause tension in the retaining bolts.
(d) The nose iron will remain in position when the retaining device is released.

4. Marking of Position

The position of each nose iron, as determined by factory adjustment, shall be accurately, clearly and permanently indicated by well defined marks on the lever and nose iron, which meet on a common line.

EE. LOOPS AND CONNECTIONS

1. Design Proportion

Loops which form bearings for projecting pivots may be of any type, provided the clearance between the enclosed pivots and the body of the loop is at least ¼ in.

2. Length

All loops of like connections shall be of the same length.

3. Vertical Adjustment

Means for vertical adjustment shall be provided between the lever system and the weighbeam, which will permit independent leveling of the shelf lever when one is used. When no shelf lever is used, the connection to the weighbeam shall be adjustable. Screw adjustments shall be provided with lock nuts or equivalent device.

F. LEVER FULCRUM STANDS

1. Qualities of Castings

Castings for lever stands shall be clean, smooth, uniform, and free from blisters, blowholes and shrinkage cracks.

2. Proportions

Lever stands shall be so designed, constructed and installed that, under any practical condition of loading, the resultant force applied through the bearing will fall within the middle third of the length and width of the base.

3. Bases of Lever Stands

The base of any lever stand shall be true within $\frac{1}{32}$ in to a plane perpendicular to a vertical line through the center of the knife-edge bearing carried by the upright portion of the stand.

4. Finish of Tops of Stands

The top of any lever stand receiving a bearing steel, cap or block shall be finished smooth and shall be parallel to the base within $\frac{1}{32}$ in.

5. Anchor Bolt Holes

Two or more anchor bolt holes, 1½ in. in diameter, shall be provided in the base of each stand unless other equally effective means for anchorage is provided.

FF. CHECKS

The weighbridge, or platform, of all scales shall be equipped with devices which effectively restrict motion in any horizontal direction, so designed and constructed as to withstand adequately the horizontal forces prescribed in Sec. CC, Arts. 5 and 6. If checks of the rod or bumper type are used, they shall be adjustable.

G. WEIGHBEAMS AND ACCESSORIES

1. Requirement for Nominal Capacity

The nominal capacity as defined in Sec. B shall not exceed the scale capacity.

2. Type of Weighbeam

Full capacity weighbeams shall be provided. The graduation on tare bars shall be as specified for the main bar. Tare bars shall not be furnished for weighbeams of the registering type.

3. Ratio

A pivot and loop shall be provided at the weighbeam tip, and the ratio at the weighbeam tip pivot shall be marked on the beam. The ratio of the scale to the weighbeam butt pivot shall be plainly and permanently stamped on the beam.

4. Poise Stop

In all scales, each weighbeam bar shall be provided with a stop to prevent movement of the weighbeam poise back of the zero notch or graduation.

5. Notches

On main bars the notches shall not be spaced closer than six to the inch. Notches shall be so formed and positioned that accurate positioning of a poise will automatically result at any graduation at which the poise may be placed.

The values of the intervals between successive notches or graduations shall be 1000 lb on the main bar, and not more than 10 lb on the fractional bar, respectively.

6. Pawl or Latch

For a poise on a notched weighbeam, the design and construction of the pawl or latch and its appurtenances shall be such that accurate positioning of the poise will automatically result at any graduation at which the poise may be placed.

7. Projections and Recesses

Poises shall be designed with the object of reducing to the minimum the number of projections and recesses that will retain foreign material.

8. Poise Bearings

Each poise shall be constructed to move along its bar without side play. The main poises shall be equipped with ball bearings.

9. Fractional Poises on Registering Weighbeams

The fractional poise on a registering weighbeam shall be constructed to stop positively at each graduation and to prevent movement beyond the last graduation. The last registration of the fractional poise shall be 990 lb.

10. Printing Lever

On registering weighbeams, a substantial type of hand grip shall be provided to facilitate the registration of the weight. The natural operation of the registering mechanism shall not cause lateral displacement of the weighbeam.

11. Receptacle for Weight Ticket

On registering weighbeams, means shall be provided to prevent placing the weight ticket in its receptacle in any position in which a weight can be registered different from that represented by the poise setting.

12. Balance Ball

The position of the balance ball shall be vertically adjustable. Unless otherwise required by law or regulation, longitudinal movement shall be controlled by means of a self-contained, hand-operated screw, or other device, which will not require the ball to be rotated in making adjustments.

13. Poises

(a) *Materials:* The exterior shell of poises shall be made of corrosion-resistant alloys, steel, iron, brass, or any other metal not softer than brass making contact with the weighbeam.

(b) *Movable Parts:* All movable elements forming a part of a poise shall be so constructed as not to be detachable without manifest mutilation of the poise. Set screws, if used to secure a poise at any point on a weighbeam, shall not be removable.

14. Identification of Parts

A serial number shall be legibly stamped on each complete weighbeam.

15. Type Figures

On type-registering weighbeams, type figures shall be made of material sufficiently hard that, under the designed conditions of use, the figures will not become battered or defaced. The figures shall be plain and raised sufficiently high to insure a clear impression upon the weight ticket or tape. They shall be so attached that they cannot become loosened or detached without a positive indication that the weighbeam is out of order.

16. Weighbeam Fulcrum Stands

Weighbeam fulcrum stands shall be so designed, constructed and installed that the resultant line of forces applied through the bearing carried by the stand will fall within the middle third of the length and width of the base.

17. Trig Loops

The play of the weighbeam in the trig loop shall be not more than 2 percent of the distance from the trig to the fulcrum pivot, nor less than 0.9 in.

18. Weighbeam Support

In all scales, the weighbeam fulcrum stand shall be securely fastened to a support sufficiently strong that deflection to an extent affecting the weighbeam performance cannot occur. If a wood box is used for the weighbeam, the shelf supporting the weighbeam shall be independent of the box.

GG. ANTI-FRICTION POINTS AND PLATES

Anti-friction contacts shall be used to limit longitudinal displacement between knife-edges and their bearings. They shall be smooth, hardened, and so designed as to provide contact at a point on the line of the knife-edge of the pivots.

H. CLEARANCES

The clearance around and between the fixed and live parts of the lever system shall be at least ¾ in. The total clearance between anti-friction points on levers and stands shall be not less than $\frac{1}{16}$ in. nor greater than ⅛ in.

HH. FACTORY ADJUSTMENTS

1. Levers

The design, workmanship and factory adjustment of the levers and weighbeam shall be such that the proper ratio of the lever arms will be maintained.

I. INTERCHANGEABILITY

Units or parts of units intended to be interchangeable with like units or parts in scales of the same design and manufacture shall be identified on the scale drawings or in the subject matter of the proposal in such manner as will clearly indicate the interchangeable parts, the manner of replacement, and the adjustment required, if any, after replacement.

II. SENSIBILITY RECIPROCAL (SR)

1. Definition

The sensibility reciprocal is the change in load required to turn the weighbeam from a position of equilibrium in the center of the trig loop to a position of equilibrium at either limit of its travel.

J. PERFORMANCE REQUIREMENTS

1. Tolerances

The tolerance in excess or deficiency when tested upon the site of use and before being accepted as satisfactory weighing machines, shall be 0.10 percent of the applied load consisting of test weights of known value; provided (1) the tolerance shall not be less than one-half the minimum weighbeam graduation on the scale being tested; and (2) a purchaser may by stipulation in the purchase order require scales on the same condition of test to meet tolerances not less than one-half, respectively, of the tolerances given above before accepting delivery.

2. Sensibility Reciprocal

For the same conditions of test stipulated in Sec. J, Art. 1, the sensibility reciprocal shall not exceed the value of the minimum weighbeam graduation.

JJ. LOCATION AND ELEVATION

1. Location

Scales shall be so located that an adequate foundation and a straight approach in line with the scale platform and of a length in excess of that of the longest vehicle to be weighed can be provided.

2. Elevation

The scale platform shall be raised to such an elevation that the drainage of surface water will be away from it and, unless space will not permit it, the approaches shall be level, or nearly level, and paved for a length equal to that of the scale platform.

K. FOUNDATIONS

1. Material

Scale foundations resting upon or extending into the ground shall be constructed of concrete. (See Sec. C, Art. 13).

The quality of materials and methods of mixing and placing the concrete shall conform to the AREA specifications for concrete and reinforced concrete.

2. Dimensions of Pit

The size of the pit shall be such as to give a vertical clearance between the scale levers and the finished floor of the pit of not less than 2 ft, and a horizontal clearance between the face of the pit walls and the scale parts below the platform, or below the weighbridge girders, and above the bases of the stands, of not less than 4 in.

3. Walls of Pit

The walls of the pit shall have a thickness at the top of not less than 12 in.

4. Waterproofing

When necessary, the pit shall be waterproofed.

5. Wall Batter

All wall surfaces next to earth subject to freezing shall be constructed with a uniform batter of not less than 1 in to the foot and as much more as necessary to permit the heaving of adjacent ground by frost action without disturbing the walls.

6. Pit Floors and Lever Stand Piers

The concrete piers supporting the lever stands shall be not less than 9 in deep, but shall in any case be carried to proper foundation. Their tops shall be above the floor of the pit a distance sufficient to prevent the accumulation of water under the bases of the stands. The floor of the pit may be designed as a mat footing of concrete, or as a simple floor not less than 4 in thick. The pit floor shall, in all cases, be smooth, with a pitch to a common point of drainage, and free from pockets in which water will stand.

7. Anchor Bolts

Anchor bolts, not less than ⅞ in. in diameter, threaded and with nuts and washers, shall be provided in the foundations for lever stands to match the bolt holes provided for securing the stands, and they shall extend into the concrete not less than 8 in.

8. Anchorage for Floating Levers

A floating lever, one exerting an upward pull at its fulcrum, shall be anchored to the foundation to resist not less than twice the upward pull produced at the fulcrum pivot by a capacity load on the scale.

KK. WEIGHBEAM HOUSE OR BOX

1. Weighbeam House or Box

When the scale is not located in a building, the weighbeam shall be adequately protected from the weather by being enclosed in a house or box. When a scale is located in a building, it shall, when necessary, be similarly protected from injury.

2. Design

The minimum inside width of the weighbeam house shall be 4 ft, and the minimum length shall be sufficient to allow the installation therein of the beam shelf and weighbeam. It shall be provided with windows of such size and location as will give the weigher, when weighing, a clear and unobstructed view of the scale platform and approaches. The windows shall be glazed with clear glass or clear wire glass. If the weighbeam is required to be boxed, the box shall be of such size as to suitably enclose the beam shelf and weighbeam. It shall be provided with a hinged door, or doors, of such size and in such location as to give the weigher clear and unobstructed access to the weighbeam.

3. Clearance

A clearance of not less than 1 in shall be provided between the inside of the scale house and the weighbeam supports and shelf. The clearance between the edge of the platform and weighbeam pillar, weighbeam box or weighbeam house shall be sufficient to permit the normal functions of weighing the widest loads required to be handled.

L. INSTALLATION

1. Fastening of Stands

After alining the stands, the anchor bolt holes in the castings shall be filled with cement, sulfur or other suitable material, and the anchor bolt nuts brought down tight.

2. Alinement

All levers shall be level and connections plumb throughout the scale.

LL. PLATFORMS

1. Security Against Tipping

All scale platforms shall be proportioned so that, for any possible application of the loads specified in Sec. CC, no tipping can occur. (See Sec. C, Art. 14).

2. Timber

In all scale platforms, timber shall not be used for floorbeams, or in any members, except floor covering, required to take shearing or compressive stress perpendicular to the grain, or stress in transverse bending. Timber may be used for floor covering and, as required, for spiking or fastening strips for the floor covering. (See Sec. C, Art. 14 and Sec. LL, Art. 9).

3. Weighbridges

Weighbridge girders and floorbeams shall be made of steel conforming to Sec. B of the AREA Specifications for Steel Railway Bridges.

4. Sections and Strength

(a) Weighbridge members shall be designed in accordance with Sec. A of the AREA Specifications for Steel Railway Bridges, except as the permissible working stresses and loading conditions are modified by Secs. C and CC herein.

(b) The section moduli of main girders shall be as shown in Table 5. A representative bill of steel for each size weighbridge is also shown in the table. The members listed in

TABLE 5—REPRESENTATIVE BILLS OF STEEL FOR WEIGHBRIDGES

Member	*Platform Size in Feet*		
	45 x 10	*50 x 10*	*60 x 10*
Main Girders	S = 80.7 2–16″ WF at 50 lb 4500 lb	S = 98.2 2–18″ WF at 55 lb 5500 lb	S = 139.9 2–21″ WF at 68 lb 8100 lb or S = 128.2 2–18″ WF at 70 lb 8400 lb
Floorbeams	11–12″ WF at 36.0 lb 3498	12–12″ WF at 31.8 lb 3816	14–12″ WF at 31.8 lb 4452
Platform Edge 6″ Channel at 10.5 lb and 1½ x ⅜″ Bead	1365 lb	1490 lb	1737 lb
Fastenings	900 lb	985 lb	1150 lb
Total	10263 lb	11791 lb	15439 lb or 15739 lb

S = Required section modulus, one girder.

Table 5 have been calculated from the loading assumptions given in Table 3, and on the basis of 12-in side overhang outside the center lines of main girders and 12-in end overhang outside the centers of load bearings. Variation from the sizes given may result if other conditions of side and end overhang are actually used. Provision has been made for impact by using the working stresses given in Sec. C.

5. Bracing

(a) Weighbridges ordinarily will require no bracing other than floorbeams and corner plates. End connections for floorbeams must be designed for maximum stresses produced by lateral forces.

(b) If the floorbeams are mounted above the main girders, weighbridges with solid floor construction or with transverse floor beams on 36-in centers or less will require no lateral bracing. Otherwise bracing shall be designed for the forces in Sec. CC, Art. 5.

(c) Cross Frames: Motor truck scale weighbridges with the floorbeams mounted above the main girders shall be provided with end cross frames and at least one intermediate cross frame. If the floorbeams are internally framed and the weighbridge otherwise adequately braced, the end and intermediate cross frames may be omitted.

6. Fabrication and Assembly

The weighbridges shall, when practicable, be assembled and riveted up complete in the shop. When field assembly is necessary, the parts shall be properly assembled in the shop and match-marked. Connecting holes shall be reamed to fit.

7. Platform Bearings

The tops of platform bearings contacting the weighbridge girders shall be finished to within $\frac{1}{32}$ in of a true plane. These tops shall be provided with bolt holes of sufficiently large diameter to allow for the transverse and longitudinal adjustment necessary to secure proper alinement of parts.

8. Deck

The deck or floor shall be designed so that, without exceeding the permissible stresses, it will support and distribute the capacity load and incidental forces when applied as described in Sec. CC and so as to produce the maximum stress in any part of the floor.

9. Flooring

The flooring material shall resist wear, shall under all weather conditions provide traction to power-driven vehicles, and shall be susceptible of being waterproofed. If timber is used, its quality shall be at least No. 1 Common dimension, treated with a preservative.

M. LIGHT, DRAINAGE, VENTILATION AND PIT ACCESS

1. Light

Proper lighting of the scale weighbeam and scale platform shall be provided.

2. Drainage

Adequate drainage for scale pits shall be provided and maintained.

3. Ventilation

All scale pits shall be ventilated to meet the needs of each particular case, the object being to minimize the amount of moisture in the air in the pit and so to retard rusting of scale parts and structural steel.

4. Pit Access

Entrance of adequate size shall be provided through the foundation wall or neck of the pit.

MM. PROTECTION FROM CORROSION

The finish and treatment of all surfaces shall be such as to insure good appearance and satisfactory resistance to corrosion. The surface treatment shall be durable and appropriate for the intended uses.

Report on Assignment 4

Waterfront Terminals

L. C. Harman (chairman, subcommittee), M. H. Aldrich, C. J. Astrue, F. E. Austerman, E. G. Brisbin, W. H. Goold, J. L. Loida, B. G. Packard, R. H. Peak, Jr., G. L. Roberts, H. T. Roebuck, W. C. Sadler, H. L. Scribner, J. N. Todd, J. C. Warren.

Your committee this year presents the following report, which is submitted as information.

Ore Piers on the Atlantic Seaboard

Deposits of high-grade iron ores in the United States are being rapidly depleted, and as no new large deposits of such ore are being discovered in this country it has been made necessary to seek deposits of high-grade ores in other countries. Also, we are to a large extent dependent on foreign countries for a source of many other high-grade ores. As the result of these shortages in our country, and with the development of sources of ores outside the continental United States, the railroads have already constructed and are now constructing huge piers or docks for the handling of ores. Principal imports are iron ore, bauxite, chrome, lead, zinc, phosphate rock, manganese, ferro-manganese, sulphur and pig iron.

The large majority of the installations are piers, but there are several important installations on docks. Wharf operations are similar to those on a pier, except that activities are confined to one side of the structure. While the primary function of these facilities is for discharging ores from ships to cars, some installations are arranged to transfer ore and other mineral products from cars to ships. Various types of ships are used in this trade—Victory, Liberty, colliers and ore carriers. At the present time huge open-type ore carriers are being constructed, or are in the planning stage, each capable of carrying as much as 80,000 tons for the iron ore trade.

Pier substructure is usually constructed with a concrete deck supported on timber, steel or concrete piles, depending upon the salinity of the water and its infestation by marine boring animals. Where timber piles are used the deck is placed on the piles at or near mean low water and is brought up to the desired elevation for the top of deck by filling either with earth or with concrete. The length of the pier depends upon the number of unloading towers used and the length and number of ships to be worked.

The widths of the pier are variable according to the design of unloading tower and number of tracks to be placed on the pier.

Where there are strong winds and tides it is necessary to have some type of fender to protect the structure. This is commonly constructed of timber.

Structural steel unloading or loading towers are mounted on rails parallel to the edge of the pier or wharf, which permit unloading from any hold of a ship without the necessity of moving the vessel to permit unloading from the different holds—the number of towers depending upon the quantity of ore to be handled. The tower is constructed of structural steel shapes, with a hinged cantilever bridge on each side extending out over ships, which can be raised to clear their rigging while they are being docked or when the unloading tower is being moved from one hatch to another. A traveling, man trolley is supported by tracks on the tower and bridge, with clamshell bucket which may vary in sizes from 60 to 280 cu ft capacity. This bucket operates on an average cycle of 45 sec, and dumps into a steel receiving hopper within the tower, of sufficient capacity to hold two or more cars of ore. The elevation of the bridge above the water should be sufficient to take care of the largest vessel served or contemplated. The present tendency is to use larger buckets.

There are two methods of handling ore from this point, depending upon whether the ore is loaded directly into railroad cars on tracks on the pier or whether it is conveyed by a belt to a loading tower or tipple some distance away. If handled by cars on tracks located on the pier, the ore is dumped from the receiving hopper onto feeders which fill a weighing hopper, where it is weighed automatically to the desired weight. From the weighing hopper it is discharged by gates into railroad cars. The number of tracks on the pier are variable, depending upon its width and the number of unloading towers on the pier. It is desirable to have one track for each unloading tower, with one or two spares for the placing of empty cars while loads are being removed. In this system there is interference with the unloading while empty cars are being placed and loaded cars pulled.

If the conveyor belt system is used the ore in the hopper is transferred by means of a feeder onto an endless conveyor belt. The belts are supported by heavy-duty idlers mounted on structural steel framing and extend from the furthest out unloading point on the pier to a loading tower or tipple above tracks on which railway cars are loaded. The widths of the belts now used vary from 48 to 52 in, and are constructed for heavy-duty service. These belts travel at speeds varying from 400 to 615 ft per min and are capable of carrying ore weighing 150 lb per cu ft at rates up to 3300 tons per hour, depending upon the speed and width of belt.

Receiving hoppers in the car loading structure are quite large, some having a capacity of 600 tons so as to act as surge bins to absorb the continuous flow of ore from the belt. Apron feeders are located below the belts to transfer the ore into spring-mounted scale hoppers, which are arranged in pairs with sufficient distance between to discharge the ore into railroad cars approximately over the car trucks. Each scale is equipped with an electric weighing recorder that stamps on the bill of lading the correct weight of the shipment. The scales and hoppers are so designed and arranged that a car may be loaded from only one of the twin hoppers if desired.

Track arrangements under the tipple are variable according to local conditions. In the majority of cases empty cars are placed on two tracks serving the tipple, and are moved by electric pusher, diesel-electric pusher, car puller, switch engine, or some other arrangement, to the proper point underneath the tipple where they are loaded and then pushed or pulled down into a loaded yard. There is one installation where the tipple is located on a semi-circular track, one end connecting to an empty yard, and the other to the loaded yard. With this arrangement there is no interference with the loading while placing empty cars to be loaded. This system offers the minimum of interference to the loading of cars.

In some instances where belts are used to handle the bulk of the ore, tracks are extended out on the pier to take care of the ore that is cleaned up from the bottoms of vessels. This method saves the expense of operating unloading towers and belt conveyors.

There are various methods of cleaning up the ore in the bottoms of vessels after the free digging ore has been removed. This clean-up job is usually done with bulldozers, slushers, payloaders and tubs, the ore being loaded into cars by the ship's rigging.

Floodlight towers and general lighting should provide illumination for the entire layout.

Radio telephone, telephone system, teletype, and inter-phone communication should be provided for the facilities. Horns are sometimes used for signaling to the different units.

The cleaning of cars before being used for the loading of ores presents quite a problem. Waste material accumulates rapidly and frequently has to be removed. Separate tracks adjacent to the empty yard are commonly provided for cleaning cars by air and washing.

In support of this facility, a sub-station and service and maintenance buildings are usually constructed adjacent to the pier.

Report on Assignment 5

Study of the Handling of LCL Freight by Conveyors

F. E. Austerman (chairman, subcommittee), C. J. Astrue, W. O. Boessneck, W. S. Broome, K. L. Clark, O. Fischer, Wm. J. Hedley, B. Laubenfels, C. H. Mottier, J. N. Todd.

This is a final report, submitted as information.

Facilities for the mechanical handling of LCL freight were first reported in the Proceedings, Vol. 49, 1948, page 113. At that time there were few conveyors handling LCL freight in railroad freight houses. Conveyors had been installed in Railway Express houses as early as 1938. A full description of such conveyors is included in the Manual of Mechanical Handling Equipment in Railway Express Service, dated February 1950. This manual recommends the overhead chain conveyor, and describes an installation in Jacksonville, Fla. The first conveyors were copied from the production-line handling facilities of automobile manufacturers and had a reported speed of 120 ft per min.

The last previous report of your committee on the subject of conveyor handling of LCL freight is contained in the Proceedings, Vol. 54, 1953, page 511. Such conveyors are known as overhead chain and in-floor towing conveyors. Both types are described in the Vol. 54 report. Since that report a number of floor-type towing conveyors have been installed. With the replacement of multi-story freight houses in congested metropolitan areas, to outlying one-story freight houses, towing conveyors have been planned and installed in many of these new freight houses. Although most new freight houses have been designed in the form of a rectangle, sometimes nearly square, the Santa Fe recently constructd a freight house in the shape of an "E", with tracks in the open sections. Two floor-type towing conveyors were installed in this freight house. The towing conveyors

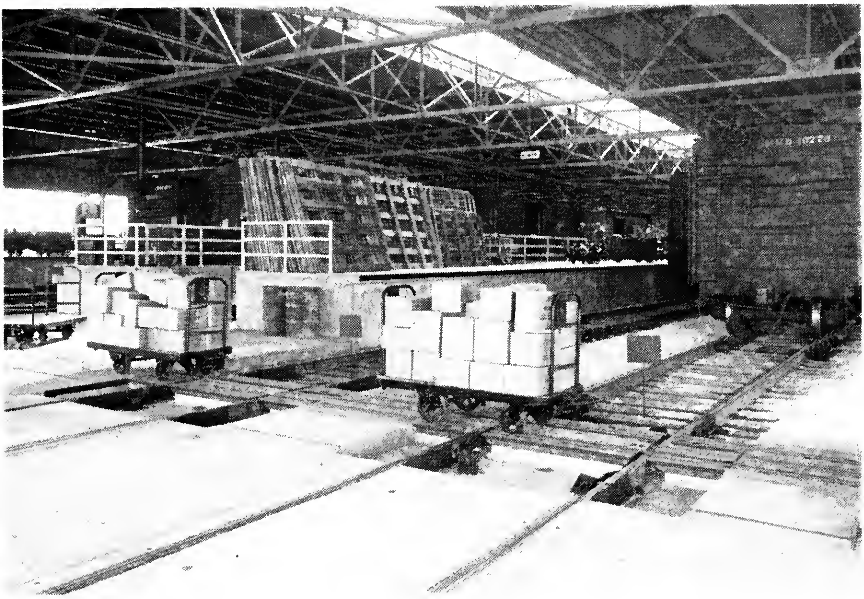

Fig. 1—Freight house of the Atchison, Topeka & Santa Fe Railway at Chicago, showing conveyor chain crossing tracks, thereby eliminating bridging.

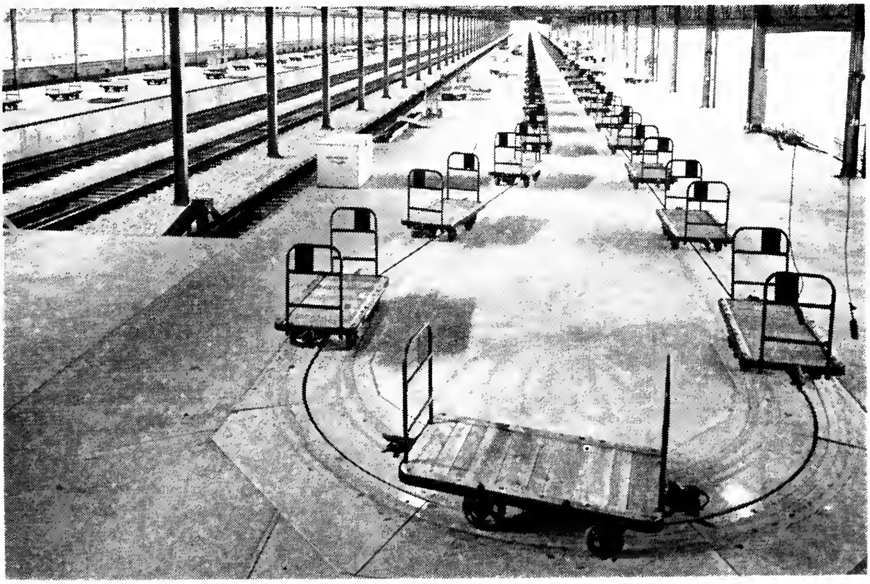

Fig. 2—Santa Fe freight house at Chicago, showing 2 towing conveyors on 3 platforms with a capacity of 500 trailers.

Fig. 3—Freight house of the Chicago, Burlington & Quincy Railroad at Morton Park, Ill., showing in-floor towing conveyor in operation.

Fig. 4—Burlington freight house at Chicago, showing overhead conveyor in operation.

consist of a roller-type chain conveyor in the floor of the car-floor-height platform, with a special slot opening. Built in the chain, 15 ft apart, are catches—devices that couple to a pin dropped from the four-wheel trailers. The entire towing conveyor system has a capacity of 500 trailers. The roller chain moves at a variable speed of 110 to 160 ft per min. The towing conveyors operate on two separate circuits, one serving the three outbound tracks, and the other the inbound tracks. This freight house is 1325 ft long and 204 ft wide. The 6 tracks handle 160 railroad cars and are under 1 roof with the platforms. A unique feature of the conveyor is that the in-floor track descends a ramp at the end of each platform and then crosses the railroad tracks at that end of the freight house. More details of this installation are described in the Dec. 1, 1952, issue of the Railway Age, and the December 1952 issue of the Modern Railroads.

The overhead and the in-floor-type towing conveyors are fast becoming an important part of the design of new freight houses and in the modernizing of older freight houses. They provide for the continuous movement of loaded trailers as well as returning the empty trailers where needed. The towing conveyor should be routed to serve the highway trucking tailboard area as well as along the freight house tracks. An area adjacent to the conveyor should be provided for easy storage of excess trailers. A towing conveyor for inbound as well as another for outbound freight provides the most economical installation. Towing conveyors can make sharp turns, thereby adapting them for use in both new and old freight houses.

The advantage of the overhead towing conveyor is the simpler and more economical installation in existing freight houses. It would also be easier to reroute or revise the overhead chain if necessary.

The advantages of the in-floor type towing conveyor are as follows:

The pull of this type is from the frame of the trailer.

All the attachments to the trailer are below the platform of the trailer and are less liable to be damaged.

There are no overhead chains to limit clearance.

Installations can cross railroad tracks.

Pin raises and lowers into a moving chain by a foot pedal on either side of the trailer.

Longer loads can be handled with the trailer connected through the floor.

The trailers follow the slot in the floor more closely, thereby using a narrower aisle.

Where it is necessary to cross railroad tracks, the in-floor towing conveyor must descend a ramp to track level, but can cross a specially designed crossing. For the overhead type of towing conveyor a movable bridge must be provided and the overhead chain must be disconnected when railroad cars are moved.

The development of the towing conveyor has solved many problems in the mechanical handling of LCL freight, and will be utilized more for the economical handling of freight.

Report on Assignment 6

Facilities for Loading and Unloading Highway Semi-Trailers on Railroad Cars

C. F. Parvin (chairman, subcommittee), F. E. Austerman, R. F. Beck, W. O. Boessneck, E. G. Brisbin, W. S. Broome, J. C. Bussey, J. G. Campbell, G. H. Chabot, F. A. Hess, J. E. Hoving, A. S. Krefting, H. J. McNalley, A. G. Neighbour, B. G. Packard, R. H. Peak, Jr., G. L. Roberts, R. E. Robinson, W. C. Sadler, W. H. Shoemaker, S. Shumate, J. N. Todd, J. C. Warren, G. R. Wurtele.

This report is presented as information, with the recommendation that the subject be continued.

The loading of semi-trailers on flat cars has been initiated on a number of railroads, is being considered on others, and this report will deal with the general methods in use.

The three ways of loading and unloading highway semi-trailers on flat cars are:

1. End loading and unloading.
2. Side loading and unloading.
3. Crane loading and unloading.

There are certain general considerations that apply to each method.

a. Location of Facility

Speed is one of the prime requisites to the success of this service. The facility should be located where it can be promptly and efficiently served from yards and should be readily accessible by highway. If practical, the facility should be located in the center of the area to be served.

b. Storage space for semi-trailers

Storage space in excess of trailer capacity of tracks should be provided. Some semi-trailers will be delivered after closing time. Others will not be removed on date unloaded. Loaded flat cars in excess of track capacity may be received over week ends or holidays, necessitating the unloading and holding of semi-trailers until resumption of the business week.

c. Location of parking and storage area

It is desirable to have such area close to the tracks to avoid additional handling of semi-trailers.

d. Lighting

Good lighting is essential. With late closing hours for receiving semi-trailers and early morning deliveries at destination, much of the work of loading and unloading will be done during the hours of darkness. The loading and unloading, regardless of method, is exacting work, as is the fastening of the semi-trailer on the flat car. When work is done during darkness, good lighting is necessary for speed as well as safety.

e. Space requirements

A space of approximately 35 by 12 ft should be allowed for parking area of each semi-trailer. A minimum turning radius of 35 ft is necessary.

f. General

Communication systems, including loud speakers, may be desirable to direct the drivers of tractors as well as others engaged in these operations.

Scales for weighing semi-trailers as received for loading may be required. They should be properly located between entrance and parking or loading area.

Where outside concerns handle the loading and unloading operations, their operating requirements must be considered.

An office and other necessary facilities, including fencing, may be provided.

END LOADING AND UNLOADING

Semi-trailers are backed onto or hauled off flat cars via ramp at one end of the track. The semi-trailers are moved between cars over plates of sufficient strength and width to sustain the wheels of the tractor and semi-trailers.

These plates are permanently fastened to diagonally opposite corners of the flat cars, properly hinged, to be placed clear of the end of the car when not in use.

This service is generally provided with flat cars especially equipped.

One railroad now providing this service has at one terminal six tracks of approximately twelve 40-ft car capacity each. A truck driver backs a tractor and semi-trailer over 12 cars without stopping, at a speed equivalent to a slow walk. The tractor unit used by this railroad has a hydraulic arrangement on the fifth wheel whereby the front of the trailer is raised approximately 17 in. This saves the time and labor required to raise and lower the small dolly wheels that support the front of the semi-trailer when the tractor is detached, and still permits dolly wheels to clear the edge of the flat car when moving to and from the ramp, permitting the use of a shorter ramp.

It is desirable to provide for the free movement of employees from one flat car to another on a single track. The construction of some flat cars permits employees to walk along the side of the car when loaded. Where the construction of the car does not permit such movement, it may be desirable to construct a platform at car floor height along the track for the use of employees engaged in the loading and unloading operations.

Advantages of this method are:

Usually, existing stub end tracks can be used for the service and a ramp placed at the end of track or tracks. The ramp can be either portable or permanent.

Facilities can be more readily expanded. By furnishing portable ramps at outlying point service can be given at other than large terminals. There are on the market portable ramps of both the light-weight metal type and heavier models to be towed by tractors.

Requires a minimum of area parallel to the tracks. At the unloading end, a distance of at least 150 ft is desirable to permit placing of ramp and provide sufficient turning space.

Disadvantages of this method are:

The unloading of trailers must be one at a time and from the same end of the car from which loaded. This requires careful planning of location and track arrangement to prevent necessity for turning cars upon arrival and before placement. One railroad, finding it impractical to make one terminal fit the unloading direction for several other terminals, paved the track area at the ladder end of the stub track and uses a portable ramp.

Trailers must be unloaded in the reverse order in which loaded. This can be mitigated by having several short tracks rather than a few long ones, thereby permitting simultaneous unloading operation. If longer tracks are used, the operation will be speeded by cutting the draft of cars at a predetermined location and placing a portable ramp. In this manner, two loading and unloading operations per track can be carried on at the same time. The opening between separated cars should be at least 150 ft to permit the placing of the ramp and the turning of tractors and semi-trailers at the bottom of the ramp. The area should be paved and proper driveway provided to the parking area.

SIDE LOADING AND UNLOADING

In one method of side loading and unloading, the loading area adjacent to the track must be at car floor height. Semi-trailers will be moved on and off the flat cars by either the regular hauling tractor or by tractors specially designed for short turning radius and a resultant better maneuverability.

Some flat cars are being specially designed for this service which provide for lower floors to improve clearance.

A second method is where trailers are placed on or removed from a car by a large fork-lift type truck from the roadway at track level. This piece of equipment has been proposed but not yet fully developed.

In addition to the loading area, a parking area must be provided, preferably adjacent to the tracks. Semi-trailers should be parked at right angles to the tracks. The width of this area should be at least 100 ft, and more is desirable. This width is the minimum that will permit the parking of semi-trailers while loading or unloading is in progress. The parking of semi-trailers at right angles to the track is desirable, particularly if the trailers are not loaded in the same direction on the flat cars. If semi-trailers are not parked adjacent to the tracks, then a loading area of at least 40 ft must be allowed for maneuverability in loading and unloading operations.

By parking semi-trailers diagonally to the track, a somewhat narrower width of parking area is possible. However, this type of parking restricts the movement from the parking area to the loading area.

When raised loading areas are used, the opening between the platform and the edge of the car should be not over 5 in, unless plates are used to span the distance between the car and the platform. In some cases it may be necessary to secure authority from either the railroad or local or state authorities governing such clearance.

Advantages of these methods are:

Simultaneous handling of semi-trailers on or off flat cars, limited generally by the number of tractors available.

Semi-trailers can be unloaded regardless of direction in which loaded.

Trailers may be loaded or unloaded in any desired order.

Longer tracks may be used, due to the ability of working at several locations at the same time.

Disadvantages of these methods are:

Depressed tracks, or platforms at car floor level, are costly.

Wide areas are required adjacent to one side of each track.

Heavy-capacity bearing surface must be provided in the loading area where the heavy-duty fork-lift trucks are used.

The close clearance required between track and adjacent platform may restrict engines and other equipment on this portion of track. If not practical to provide close clearance, plates must be furnished between the cars and platform, which necessitates additional labor for placing and removing these plates.

CRANE LOADING AND UNLOADING

To date, this committee has no knowledge of any proposal for using this method.

The advantage would be:

The use of a crane—particularly an overhead traveling type—would permit loading and unloading of semi-trailers on flat cars with minimum ground area adjacent to the tracks.

Semi-trailers could be loaded or unloaded in any desired order.

The disadvantages would be:

The high initial cost of the crane.

Report on Assignment 7

Electronic Devices in Yards and Terminals

Collaborating with Communications and Electrical Section, AAR

R. F. Beck (chairman, subcommittee), F. E. Austerman, A. E. Biermann, N. C. L. Brown, G. H. Chabot, H. P. Clapp, W. H. Giles, W. H. Goold, H. J. Gordon, H. J. McNally, C. E. Merriman, A. G. Neighbour, C. M. Ratliff, L. W. Robinson, M. S. Rose, J. N. Todd, J. C. Warren.

Your committee presents the following final report, which is submitted as information with the recommendation that the subject be discontinued.

Important advances have been made within recent years in the application and use of electronic devices which have contributed immeasurably to the increased efficiency of our freight terminals. These devices have greatly expedited traffic through terminals, provided increasingly better car reports and accounting procedures, and promoted over-all safety.

Paging and Talk-Back Speakers—Intercom Systems

Paging and talk-back speakers, together with intercom, are so interrelated that they can best be described together. Paging and talk-back speakers used in conjunction with intercom systems are in use in most freight terminals. They are providing excellent communication facilities for the effective handling of freight.

Paging and talk-back speakers are used to direct outside yard operations, while intercom systems are best adapted to communication between offices controlling yard operations. Paging speakers are usually placed on high poles to blanket an area and are used to give instruction or to call yard personnel to a talk-back speaker for a two-way conversation. The talk-back speakers are usually located adjacent to yard leads, departure tracks, hump areas, or other advantageous locations. They are placed either on low posts, or, where clearance conditions prevail, at near ground level alongside or adjacent to switch stands.

The talk-back speakers in some yards, in addition to performing their normal function, can also be used as paging speakers by connecting several of them together to blanket an area. Some yard installations also have numerous strategically located telephones which can be connected into the paging speakers by pressing a button on the telephone.

For yard operations, control of the paging and talk-back speakers usually rests with a yardmaster who directs these operations from a console in his office. The intercom system between various yard offices is also at his disposal. Some of the larger yards have several independent systems of paging and talk-back speakers in operation concurrently. Several of these installations enable a general yardmaster to cut in on any or all systems. Others limit the general yardmaster to monitoring conversation, while providing direct communication to his assistants via intercom. In any event, the system is so flexible that many different combinations may be utilized.

The installation of paging and portable talk-back speakers, together with intercom, has greatly expedited the handling of LCL freight in some terminals. One checker at his semi-enclosed, sound-proofed desk can work simultaneously with several crews, where formerly a checker was required with each crew. The crew caller plugs the lead of his portable talk-back into outlets spaced one car length apart on the loading platform, and hangs his "talk-back" in the car. Paging speakers provide over-all direction and are very effective in spotting cars at correct locations. The over-all operation is generally controlled from a console in the general foreman's office. He has direct access via intercom with the agent, his staff, and the checker.

The use of paging speakers and intercom system is an integral part of retarder yard operation. Paging speakers are sometimes used to inform the pin puller how many cars to cut, and to issue trimming instructions to the hump engine. The close liason required between yardmaster, humpmaster, retarder operator, and weigh clerk to hump cars efficiently is provided by an intercom system. In some yards car inspectors in pits on the hump lead are also integrated into the system.

Paging and talk-back speakers are also used to direct operations in marine terminals, float bridges, coal and ore piers, icing operations, repair yards, etc.

Radio

Many varied yard operations have been facilitated by the use of radio. Base, mobile, and portable radio are the different types currently employed, and may be used in conjunction with one another. Two-way radio predominates the field, but some installations use one-way radio. Authorization for use of radio transmitting equipment must be obtained from the federal government. Detailed information on procedures is usually available from the Communications Department of the railroad.

Base radio may be described as a combination transmitting and receiving station at a fixed location, which is used primarily for communication with portable and mobile units, and is customarily located at the nerve center of yard operations. Mobile radio placed in moving equipment, and portable radio carried by yard personnel, are also used as combination transmitting and receiving stations. In some yards, however, mobile radio and portable radio are limited to either transmitting or receiving.

Some retarder yards use base radio at the crest of the hump and mobile radio located in the cab of the hump engine to provide two-way communication between humpmaster and crewmen. This serves as an effective aid for directing humping and trimming operations. Similarly, this type of communication is also being used between yardmasters and switch crews in the yard or terminal area to coordinate movements and prevent delays. In addition, base radio and mobile radio are being employed effectively between dispatcher, yardmaster, and road crews to coordinate switching movements in yards with the arrival of trains, provide quicker departure for outbound trains, and avoid holding and flagging trains on main track. In some terminals both engine and caboose are equipped with two-way radio.

Many marine terminals are also using a base radio station, usually located in the tug dispatcher's office, and mobile equipment installed in tug boats for two-way communication. Tug boat operations are more effectively controlled, resulting in faster handling of freight.

Portable two-way radio carried by yard personnel is rapidly being placed in service in many yards. Car checkers communicate initials and numbers of cars to a central office where they are taken by a yard clerk. Car inspectors notify their supervisors of any defects or talk to one another when making air brake tests prior to a train's departure. Yard switching crews communicate with each other and with the crewmen provided with mobile radio in the engine cab.

Another recent innovation is the installation of mobile radio in motor vehicles, which provides two-way communication with a base radio station. Diesel oil, car inspector, and maintenance trucks in some terminals are dispatched from a central location by this means. Trainmasters at a few terminals are expediting traffic at difficult locations through the use of mobile radio installed in their cars, which provides two-way communication with a base radio station at yard headquarters.

Many uses have been found for both mobile and portable one-way radio. One installation provides car checkers with one-way portable radio, enabling automatic recording mechanisms to record initials and numbers of cars. In another installation the switch crew foreman uses portable transmitting equipment only to give instructions to the crewmen who are provided with receiving equipment.

Recently, portable one-way radio has been used in conjunction with paging and talk-back speakers. In at least one yard car inspectors, using portable transmitters, can contact yard personnel, in addition to their supervisors, over the paging speakers. In other yards switch foremen provided with portable transmitting equipment can issue instructions to the crewmen. These instructions are heard over the mobile receiving set in the engine and by other members of the switch crew via the paging speakers. Similarly, the crewmen's conversation is heard through the paging speakers for all of the crew to hear. Thus one-way radio, when combined with paging and talk-back speakers, becomes in effect a two-way system and can be used in many varied yard operations.

In some yards where personnel using portable radio are separated by considerable distances, contact with one another is provided through the use of a mobile relay radio station. This station receives from the portable equipment and retransmits at higher power levels, thus providing reception by the separated personnel. Effective control of the personnel can be provided by cutting the supervisor into the system.

Signals

Signal indications of various types have undergrone a great transformation within the recent past and their use has been greatly expanded. This is especially true in the many retarder yards recently completed and presently under construction.

Many of these new yards use signal indication for controlling the movement of cars to the hump, although radio is an adjunct in some of them. Humping is usually controlled by a color-light signal at the crest of the hump, the aspects of which are repeated by signals along the hump lead. One yard repeats the aspects of the hump signal in the cab of the hump engine, where a change of aspect is signaled by a bell. Trimmer signals are also in use for controlling trimming operations and are usually interlocked with the hump signals to prevent the humping of cars during these operations.

In many cases dragging equipment detectors are located on the approach hump lead to warn the humpmaster. At least one yard uses a device to detect broken wheel flanges. Retarder operators are usually informed by clearance indications when cars have passed beyond clearance at the hump end of the classification yard.

Various kinds of track occupancy and clearance indicators are in operation, especially in receiving and departure yards. The indications may be shown on a panel at the nerve center of yard operations.

Automatic Switching

The development of automatic switching in hump retarder operation has greatly expedited the classification of cars. Automatic switching is accomplished through a control mechanism usually placed at the crest of the hump, in which the final track disposition of any car, or cut of cars, moving by gravity to the classification yard, is selected by pushing a button on the control panel. The switches the car, or cut of cars, must pass through are automatically positioned just ahead of the car as it passes from the crest of hump to the classification track.

Automatic Retardation

Various devices have recently been developed for assisting the retarder operator to control the speed of cars moving by gravity to the classification yard, thus providing the maximum operating capacity with minimum damage to cars and lading.

In several yards an electronic-type speed indicator shows the retarder operator the speed of cars moving under his control and assists him to reduce any error in judgment in releasing cars for proper coupling speeds. In addition, the speed indicator provides him with information for handling cars when visibility is poor.

In other yards the degree of retardation to be applied, and the speeds at which cars are to be released from retarders, are pre-selected by the retarder operator. Car speeds are measured and cars are released automatically at the pre-selected speeds. As long as weight and rolling resistance characteristics are similar, the selection is left unchanged and the operation is automatic.

In another yard a mechanism classifies the weight of cars in motion. These classifications are used to set the degree of retardation to be applied. Also, the speed at which cars are to be released is pre-selected automatically in relation to the classified weights. An electronic-type speed indicating device measures the car speed and the retarders automatically release the car at the pre-selected speed. The retarder operator serves to monitor the operation and take care of unusual conditions.

Another system measures the rolling resistance of a car as it moves from the hump retarder to the group retarder. This measurement is used as an index of the resistance to be encountered from the group retarder to tangent track in the classification yard. Automatically, a releasing speed is selected sufficient to move the car through this distance and arrive at tangent track at a safe coupling speed. The degree of retardation is set automatically in accordance with weight classifications determined by a mechanism which classifies the weights of cars in motion. The speed is measured by an electronic-type speed indicator and the car is released automatically at the prescribed speed. The retarder operator serves to monitor the operation and take care of unusual conditions.

Electronic Scales

The electronic scale is playing an increasing role in yard operation. Load cells, incorporating resistance wire strain gages, form the load receiving element. One type of electronic scale uses only load cells mounted to support the weigh bridge, and electrically connected to the electronic recording apparatus. Another type mounts the load cells between the weigh bridge and the lever system, resulting in weights from both electronic apparatus and hand weigh beams. A third type is now being offered by one manufacturer and may be considered experimental. It involves the use of a conventional lever system with an electronic weigh cell introduced into the steelyard rod.

Electronic scales are being used for both spot and motion weighing. Where scales are placed on a 3 percent grade for motion weighing, it is necessary to use new methods of indicating when a car is alone on the scale and ready for weighing. Both photo-electric cells and a system of counting relays are in use.

Car Reporting Systems

Greater efficiency in the operation of freight terminals with their ever-increasing use of modern communications and equipment has been made possible by effective methods of recording and reporting car movements. Teletype, in conjunction with card to tape and punch card machines, is currently being used in many terminals. These machines are being used to prepare switch lists, wheel reports, advance consists, arrival reports, train reports, and car tags. This information has resulted in faster movement through terminals, in addition to providing better traffic, car service, and accounting reports.

Another recent development applicable to car reporting systems is the introduction of carrier systems which provide for multiple circuits over one pair of lines. They are being used to relay information between terminals. These circuits include teletype, voice, telegraph, etc.

Television

Several roads have experimented with television as a visual aid. The equipment included devices for pickup, transmission, and viewing. These experiments have shown that television can be used to secure car numbers, detect defects in cars, and give yardmasters a view of yard operations.

Report of Committee 6—Buildings

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T. S. Williams
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, including recommended revisions .... page 426

2. Specifications for railway buildings.

   Report on specification for 4.2-in pitch corrugated asbestos-cement siding and roofing sheets and their applications, submitted for adoption and inclusion in the Manual .... page 427

3. Shop facilities for diesel locomotives, collaborating with Electrical Section, AAR, Committee 12, and Fire Protection and Insurance Section, AAR, Committee 2.

   Progress report, submitted as information with the recommendation that the material be published in the Manual a year hence .... page 429

4. Wind loading for railway building structures.

   Progress report, including recommended Manual revisions .... page 444

9. Air conditioning, collaborating with Electrical Section, AAR.

   Final report covering air conditioning of railroad office buildings, submitted as information .... page 445

The Committee on Buildings,
O. W. Stephens, *Chairman*.

AREA Bulletin 518, November 1954.

Report on Assignment 1

Revision of Manual

D. E. Perrine (chairman, subcommittee), C. M. Angel, C. E. Booth, W. G. Burres, R. R. Cahal, D. W. Converse, C. E. Defendorf, L. A. Durham, Jr., R. L. Fletcher, C. S. Graves, J. W. Hayes, J. F. Hendrickson, M. L. Koehler, N. C. LeClaire, L. R. Morgan, T. V. Pyle, J. B. Schaub, E. W. Scripture, Jr., B. M. Stephens, R. C. Turnbell, S. G. Urban, J. W. Westwood, O. G. Wilbur.

Your committee offers the following recommendations with respect to the material in its chapter in the Manual:

Pages 6–9–4 to 6–9–6, incl.

HOT ASPHALT MASTIC FLOORS

Reapprove with the following change:

Delete Art. 5. Mineral Aggregate, on page 6–9–5 and substitute the following:

5. Mineral Aggregate

The aggregate shall be clean, durable limestone, trap rock, granite or air-cooled blast-furnace slag uniform in quality, free from dirt, dust, screenings, soft stone or other foreign matter. It shall be broken as nearly cubicle as possible, rough surfaced and sharp angled, and shall be of compact texture and uniform grain. The size and grading shall be as specified in Art. 6, this specification.

The aggregate shall be subject to abrasion and toughness tests conducted by the engineer in accordance with current ASTM Methods of Tests, designations D2 and D3. Requirements shall conform to current ASTM specifications for stone and slag.

Pages 6–2–1 to 6–2–3, incl.

EXCAVATION, FILLING AND BACKFILLING

Reapprove with the following change:

Delete Art. 6. Soil Test, on page 6–2–2 and substitute the following:

6. Soil Test

Soil tests shall be made before any foundation work is placed. Foundation soils, exploration and tests shall conform to current specifications as outlined in Physical Properties of Earth Materials, Part 1, Chapter 1 of the AREA Manual.

Pages 6–5–1 to 6–5–5, incl.

STRUCTURAL STEEL

Reapprove with the following change:

Delete Art. 5. Wind Load, on page 6–5–4 and substitute the following:

5. Wind Load

Wind load requirements shall be based upon the current American Standards Association recommendations for minimum wind load requirements.

Report on Assignment 2

Specifications for Railway Buildings

S. E. Kvenberg (chairman, subcommittee), C. M. Angel, H. M. Booth, W. G. Burres, R. R. Cahal, C. E. Close, D. W. Converse, L. B. Curtiss, R. L. Fletcher, M. L. Koehler, B. M. Murdoch, D. E. Perrine, C. L. Robinson, J. J. Schnebelen, J. T. Schoener, E. W. Scripture, Jr., R. C. Turnbell, J. W. Wagner, O. G. Wilbur.

Your committee submits the following specification with the recommendation that it be adopted for inclusion in the Manual at the end of Part 10—Roofing and Siding.

SPECIFICATION FOR 4.2-IN PITCH CORRUGATED ASBESTOS-CEMENT SIDING AND ROOFING SHEETS AND THEIR APPLICATIONS

1. General

The contractor shall furnish all labor, material, tools and equipment needed entirely to complete the application of asbestos-cement corrugated siding (and/or roofing) as called for on the drawings and as directed by the engineer in charge.

2. Approved Characteristics of Sheets and Accessories

Asbestos-cement corrugated sheets and accessories shall conform to current ASTM Specifications designation C–221, and shall have the following characteristics:

a. Pitch of corrugations: 4.2 in.
b. Depth of corrugations: 1½ in.
c. Approximate thickness of sheets: ⅜ in.
d. Width of sheets: 42 in or 10 corrugations.
e. Length of sheets: Multiples of 6 in up to 12 ft.
f. Minimum possible curved radius of sheets with arc parallel to length: 60 in.
g. Minimum possible curved radius of sheets with arc parallel to width: 48 in.
h. Square corners on sheets for staggered joint construction.
i. Clipped corners on sheets for straight joint construction.
j. Ridge roll: ½ round, 3½-in radius, 4 to 12 ft long, ⅜ in thick.
k. Ridge roll joint battens: 6 in long, ⅜ in thick, 3-in radius.
l. Corner roll: 6 by 6 in bent to 3-in radius, 8 ft long, ¼ in thick.
m. Corner roll joint battens: 6 by 6 in bent to 3⅜-in radius, 6 in long, ¼ in thick.

3. Approved Fastenings

a. Corrosion-resistant lead-head bolts.
b. Corrosion-resistant round-head stove bolts.
c. Galvanized, lead-head drive screws.
d. Galvanized clips.
e. Galvanized toggles.
f. Other types furnished by the manufacturer shall be approved by the engineer.

4. Storage

Sheets and all accessories are to be kept clean and dry. Sheets are to be piled on firm, level supports spaced on approximately 12-in centers and extending full width, and are not to be piled to a height exceeding 18 in. If sheets are delivered strapped, they are not to be unstrapped until ready for application. Asphalt closure strips are to be stored in a horizontal position.

5. General Construction

a. The minimum roof pitch shall be 3 in. In heavy-snow country, 4 in.
b. The side lap on both roofing and siding shall be one corrugation.
c. The end lap on both roofing and siding shall be not less than 6 in.
d. The roof purlin spacing shall be not greater than 54-in centers. In heavy-snow country, 45-in centers.
e. The side girt spacing shall be not greater than 66 in.
f. Sheets must be of proper length so that all end laps will occur over a purlin or girt and so that fasteners at ends of sheets will pass through both upper and underlying sheets. Fasteners must be tight against the back of purlin or girt.
g. Clips shall be spaced on approximately 18-in centers on main body and on approximately 12-in centers along all eaves and ridges.
h. Drive screws shall be placed on approximately 12-in centers.
i. Side lap bolts shall be spaced one in each side lap midway between purlins or girts on spans up to 4 ft, and 2 bolts evenly spaced on greater spans.
j. Washers shall be used wherever the head (except lead-head bolts) or nut of fasteners comes in contact with the asbestos-cement sheets or accessories.
k. Bolts and drive screws (except lead-head) shall be adequately covered on the weather side with gray asbestos roof putty or with a heavy coat of white lead.
l. For general purposes, flashing material will be either 4-lb chemical soft lead or $2\frac{1}{2}$-lb, 6 percent antimonial lead. Expansion joint material will be either 3-lb, 6 percent antimonial lead or 16-oz soft-rolled copper.
m. Sheet lead with a bending radius greater than the thickness of the metal must always be provided, and provision must be made in fastening of the sheet lead for a coefficient of expansion $2\frac{1}{2}$ times greater than steel.
n. Flashing and ridge roll lying crosswise of the corrugations must rest on a suitable type asphaltic closure strip so that a proper weather seal is provided between the corrugated sheets and the flashing or ridge roll.

6. Roof Application

a. The first or eave course of sheets shall be laid to a guide line stretched along the entire length of the building. This line is to be placed at a point corresponding to the eave or overhang of roof.
b. Sheets shall be applied strictly in accordance with the manufacturer's instruction sheet accompanying the materials outlining procedures for either straight or staggered joint construction.
c. Asphaltic roof putty shall be laid in all side and end laps of roofing sheets only, using approximately 5 lb per 100 sq ft of roof area. This putty shall be spread evenly over ridge only of end corrugation in vertical laps and near head of underlying sheet in horizontal laps.
d. At gable ends, sheets must not overhang ends of purlins more than 2 corrugations, and an overhang within the limits of 6 to 9 in will be maintained at the eaves.
e. Holes must be drilled for bolt fastening always in high part of corrugation, $\frac{1}{32}$ in oversize for lead-head bolts and exact size for stove bolts.
f. Material piled on the roof during construction will be placed so that the load is borne entirely by framing members. Workers must always walk over framing members and on planks and chicken ladders, particularly when roof deck is wet, as the material becomes slippery.

7. Siding Application

Generally the same as roofing except that laps are not cemented. It is necessary to make special provision for holding sheets in place until the fasteners are installed. Sheets must be kept back 1 in from corner on each side for proper seating of corner roll. Where siding is placed horizontally, voids between corner roll edges and corrugations of siding must be thoroughly caulked with gray asbestos roof putty.

8. General Conditions

All materials entering into the work and all methods used by the contractor shall be subject to the approval of the engineer in charge, and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Part 1, this Chapter, shall be considered to apply with equal force to this specification.

Report on Assignment 3

Shop Facilities For Diesel Locomotives

Collaborating with Electrical Section, AAR, Committee 12, and Fire Protection and Insurance Section, AAR, Committee 2

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The committee presents as information the following recommended practice with respect to shop facilities for diesel locomotives, looking to submitting this material for adoption and inclusion in the Manual one year hence. This report is taken in part from previous reports of the committee on this assignment which appear in the Proceedings, Vol. 44, 1943, page 235; Vol. 46, 1945, page 87; and Vol. 51, 1950, page 230.

SHOP FACILITIES FOR DIESEL LOCOMOTIVES

1. General

With the accelerated trend toward dieselization on most railroads throughout the country, the provision of adequate facilities to repair and service the diesel locomotive units used for road and switching service has become essential.

There have been various schools of thought as to what facilities and processes are necessary for the proper repair and servicing of various diesel units, and although they vary considerably, they are all similar in many respects.

2. Building Arrangement

Generally, a diesel repair shop comprises a structure (either new and specifically designed for the purpose, or existing and converted for the purpose), into which diesel units are brought for heavy repairs or periodic maintenance. In some cases the same shop may also be used for servicing and the making of running repairs. When planning a new building, it is preferable to select a rectangular-shaped building equipped with through tracks or stub tracks, or a combination of both.

The size and arrangement of a diesel shop and the number of tracks, as well as equipment of the various shops, differ on various railroads, depending to some extent on the number of diesel units in service and the policy of the particular railroad.

At the present time the trend in many instances is to consolidate the various shop and repair processes used in conjunction with the repairing and servicing of diesel locomotives in one large building, and it may be expected that there will be found within the diesel repair shop various shop or repair facilities, such as machine, electrical parts, wheel, engine, steam generator boiler, tin, pipe, air brake, welding truck, battery, plumbing, filter cleaning, storeroom, lube oil storage, dispensing room, tool room, etc.

Elevated platforms should serve all tracks in the running repair bay, and separate areas or rooms should be provided for the wheel shop, battery shop, paint room, engine overhaul shop, filter and parts cleaning room, electrical shop, parts reconditioning room, air-brake room, store room, tool room, and office. The locker room, lunch room, and toilet facilities, as well as space for lube oil storage and water facilities, should be located on the lower level.

3. Overnight and Weekend Diesel Housing

In many instances small metal buildings are constructed at outlying locations to provide overnight and weekend parking or storage. In some cases pits and jacking pads are provided for making miscellaneous light repairs.

4. Equipment

In various large shops there may be found elaborate and expensive equipment, such as drop tables, body-holding devices, overhead cranes, wheel truing machines, meggers, ductors, surge comparison testers, electracers, magnaflux machines, magnaglow machines, special machine tools, automatic wheel lathes, varnish impregnating vats, electric bake ovens, degreasing machines, governor and injector testing equipment, electric arc-welding machines, oxyacetylene cutting and welding equipment, paint-spraying equipment, air-brake testing equipment, battery chargers, etc. It should also be noted that in some cases where space is available, these functional shops may also be used as the system shop, doing work on other than diesel locomotive equipment; likewise, some railroads continue to maintain separate shop buildings for some shops.

5. Fire Protection

Diesel shops should be built of fire-resistant materials throughout. Where economy in the initial investment makes necessary the use of existing frame buildings, these should be provided with reinforced concrete floors and platforms, and the superstructure should be coated with fire-retardant paint.

Ventilating hoods in servicing areas where most engine testing is done, as referred to in a following article on Heating and Ventilation, also serve to preclude the deposit of residue from the exhaust fumes of diesels on flammable roof construction, thus reducing a possible fire hazard. These hoods should be of fire-resistant construction and, where possible, equipped with steam jets to facilitate cleaning. Their use will minimize the necessity of fire-resistant painting.

The introduction of the general-purpose shop with one large building brings with it the introduction of additional fire hazards, which should be adequately guarded against from the fire prevention stand point. Good practice indicates that serious hazards should be safeguarded by the provision of separate cut-off enclosures to prevent any serious spread of fire, and enclosures should preferably be provided for lube oil storage tanks and pumping equipment, boiler room, battery repair and charging rooms, locker and wash rooms, filter cleaning room, paint storage room, as well as any other areas containing high fuel values or hazardous processes. In some cases it is desirable to provide curtain walls to divide large ceiling areas into cells as a means of controlling and confining fire, and also to provide separate enclosures for engine parts repair and injector servicing to make the rooms free from soot and smoke.

Special precaution should be taken against personnel suffocation which may possibly be encountered in the use of certain types of hand extinguishers and automatic flooding devices, such as automatic carbon dioxide flooding system, automatic spray sprinklers, high pressure fog systems, automatic foam systems, automatic dry chemical devices, etc. Notwithstanding the provision of enclosures for areas of serious hazards, there remains the large area with its numerous general hazards, such as oxyacetylene welding processes, electric arc-welding processes, spray touch-up painting, electrical equipment, varnishing, and insulation, all of which should be adequately protected by suitable extinguishers supplemented by fire hose and combination nozzles where indicated by the circumstances. In some cases portable 6-ft, or longer, pipe-mounted fog nozzles have proved very satisfactory.

Consideration should be given to the proper collection and venting of fumes and vapors from hazardous areas or operations as an alternative to providing separate enclosures for these areas and processes, since enclosures within a shop facility will impede normal shop operations and work flows, as well as the delivery of materials, parts, etc. Velocities for exhaust should comply with requirements of state codes to prevent the spread of hazardous fumes and vapors. The collection of fumes should be made by means of high-velocity type hoods, the fumes to be exhausted directly outside the building in accordance with code requirements. Approximate velocities should be 300 to 500 ft per min.

6. Heavy Repair, Running Maintenance

Diesel locomotive repairs can be divided into two general classifications: heavy repair and running maintenance. The diesel shop falling within the classification of a heavy repair shop is one equipped to handle all phases of diesel locomotive repair and overhaul. The running maintenance shop is one limited to normal terminal servicing and such operations which would not require heavy hoisting equipment and extensive tool layout.

7. Heavy Repair Shop Planning

The primary consideration in diesel shop planning is that tracks be parallel, and it is recommended that those tracks which are to be assigned for terminal servicing or running be through tracks. It is a basic consideration that the diesel locomotive be serviced on a production-line routine, with all sanding, fueling, watering and washing being accomplished on the tracks adjacent to lead tracks to the shop building. When a locomotive enters the building for the inside inspection, lubrication and minor repairs, other units follow onto the approach tracks for the outside operations. With running maintenance servicing tracks extending through the building, the serviced locomotive can be taken out of the shop without any interruption to the flow of locomotives following through the servicing operations.

8. Inspection Pit and Servicing Areas

It is generally agreed from experience in inspection and servicing that the "between run" servicing operations can best be performed on the inspection pit, served by both a depressed floor and a high-level floor, or working platform. Inspection pit details vary, but a depth of 4 ft below the top of rail seems to be generally accepted. The pit length should be from 10 to 25 ft greater than the overall length of the longest locomotives to be serviced. Consideration should be given to the installation of jacking blocks or pads to a point 7 ft from the center line of track. The same should be provided wherever body jacking is performed. Also, jacking pads should be provided wherever journal boxes or trucks will be jacked. Jacking pads could be narrower than the 14 ft width recommended for body jacking.

Drainage should be provided either by floor drains or by sumps located at proper intervals along the length of the pit. The pit walls of reinforced concrete are either carried to the height of base of the rail or to the level of the depressed floor area, with columns extended to the height of base of rail for track support. The latter detail is preferred, since it affords a positive method of draining the floor (crowned at the center into the pits), as well as an aid in pit lighting and of providing access into the pit along its entire length. The distance between centers of parallel inspection pits varies from 18 to 26 ft. This distance is established by the desired width of the high-level working platforms, except when a release track is introduced between pits requiring a minimum of approximately 23-ft track centers. The rail on inspection pits should be of a heavy section, preferably new.

The depressed floor along the inspection pits places the mechanic at proper height with the locomotive for inspection and making repairs to trucks, braking systems and other underbody equipment. The elevation of this depressed floor area varies from 2 ft 6 in to 2 ft 11 in below the top of rail on the inspection pits. The floor should be well drained and constructed with a surface that is easily cleaned. The recommended slope is ⅛ in per ft.

In some instances continuous trough floor drains, covered by cast iron grating in 3-ft sections and served by floor drains at approximately 60-ft centers, are installed to insure dry pits.

Anti-slip materials are recommended on inclines and steps. Special precautions should be taken in connection with the preparation of concrete floors in battery shops or other acidic areas, such as steam generator washout locations, to prevent deterioration of these floors.

Elevated platforms in the area between adjacent servicing tracks, as well as along the outer sides of these tracks, are generally agreed to be a necessary facility in the diesel locomotive running maintenance shop. The height of the platforms with respect to the top of rail is most generally 4 ft 8 in to 4 ft 11 in with some constructed at 5 ft 6 in. The distance from edge of platform to center line of track must be held to the minimum of 5 ft 6 in or as otherwise necessary for the proper clearance of the equipment to be served. It is recommended that platforms be constructed of noncombustible material, usually consisting of steel columns and beams or of reinforced concrete.

There has been some discussion of the apparent trend toward narrower platforms, approaching the minimum widths that will permit two material-handling trucks or transporters to pass. This trend seems to be brought about by the fact that wider platforms allow materials and parts to be left on the platforms when they should be moved to repair areas, stores or scrap for better housekeeping. Where repair areas are not located on or under platforms, suggestions have been made that track spacing might be reduced to 18 ft 6 in between track centers, except where there are columns which would make it necessary to increase platform widths sufficiently that track centers would have to be widened to approximately 21 ft.

Platforms should be provided with removable handrails along all edges, consisting of either pipe or a combination of pipe supports with chains between them. Access to the working platforms from the normal top-of-rail level floors and depressed level floors should be provided by means of stairs and ramps at the ends and at intermediate points. Access from one platform to another is most desirable, and can be accomplished by means of bridges. Such bridges must be removable and can be a simple form of gangplank, set into place and removed with a lightweight, motorized, monorail hoist.

There is also manufactured an elevator-type bridge having rails in its floor, which can be depressed into the inspection pit when necessary to move locomotives past the line of platform bridge crossing.

Electrically operated crossover bridges are by far the best means of inter-platform communication, but their control should be interlocked with the door-operating mechanism to avoid the possibility of accidents.

9. Overhead Cranes

As the nature of operations in repair areas requires handling various components, the overhead crane is an essential facility, and the following suggested capacities and lift heights should be given consideration:

Above prime mover overhaul and assembly areas, if prime movers are set on dollies under a heavy crane and rolled into and out of the overhaul area:

1½ ton, 12-ft lift above floor.

Above maintenance tracks, including depressed floor and pit tracks with elevated platforms:

2-ton, 20-ft lift above top of rail.

Above maintenance and repair tracks in a small shop handling both maintenance and repairs:

If axle-mounted wheels and traction motors will be handled separately, in addition to other parts:

5-ton, 24-ft lift above top of rail, to permit lifting larger components out of units.

If an assembly consisting of traction motor wheels, axles, and roller-bearing journal boxes will be handled as a unit:

10-ton, 24-ft lift above top of rail, to permit lifting main generators and other large components out of unit.

If locomotive body will be jacked and truck work handled by lifting one end of truck only:

20-ton, 24-ft lift above top of rail.

*If prime movers are to be lifted out of units:

30-ton, 30-ft lift above top of rail.

*If complete trucks are to be lifted:

40-ton, 30-ft lift above top of rail, assuming the same crane will also be used for lifting prime movers out of units.

*If one end of body is to be lifted without trucks attached:

60-ton, 30-ft lift above top of rail, assuming the same crane will also be used for lifting prime movers out of units.

* These crane capacities and lifts are also suitable for repair or "back" shops whether or not associated with maintenance and light repair facilities.

*If one end of locomotive is to be lifted with the trucks suspended therefrom: 100-ton, 30-ft lift above top of rail; or 36-ft lift above top of rail if locomotives are to be lifted over each other using two 100-ton cranes, one at each end of the unit.

*If complete locomotives are to be lifted with trucks suspended therefrom: 200-ton (One crane with two 100-ton trolleys), 36-ft lift above top of rail if locomotives are to be lifted over each other.

Many of the above crane capacities and lift heights can be reduced if careful check is made of the locomotives to be handled, since the figures shown are intended to cover the largest and heaviest diesel locomotives now in service.

If allowance is to be made for future types of motive power, including the gas turbine-electric, etc., certain of the above capacities should be increased considerably. As the most costly units are the larger cranes, some railroads are purchasing their larger cranes with 50 percent greater capacity than indicated above to allow for future contingencies, since the price difference usually is proportionally less than the increase in capacity.

10. Truck Replacement

For changing out wheels and trucks, transfer pits, jack and drop tables are used.

Drop tables with spacer posts, using either electric or hydraulic hoisting and racking motive power, have become the most generally accepted equipment for the truck-changing operation. Requirements as to the capacity of the drop table are dependent upon the locomotives to be serviced. Most generally those of 100-ton capacity are used to service freight and passenger locomotives, as well as switchers and road-switchers. Table tops 18 ft in length are required for 4-wheel trucks, and tops 23 ft 6 in long for 6-wheel trucks. In some instances tables 26 ft wide have been installed.

Numerous railroads are using drop tables approximately 6 ft 6 in long for exchanging individual wheel pairs, with or without traction motors. Some of these are installed separately and others in combination with drop tables or transfer tables of sufficient length to permit handling complete trucks.

Release tracks should be provided and arranged between each pair of tracks; i.e., in a 4-track shop, release tracks should be provided between tracks 1 and 2 and between tracks 3 and 4. Such an arrangement will avoid the necessity of lowering the table, its top and truck below another table top to reach the release track, and a drop table pit depth of 8 to 10 ft will be sufficient. On the other hand, the deep drop pit may cost less than the additional building width required by more than one release track, and shop operations may be more economical if the space between working tracks is clear instead of filled with wheels and trucks.

The cost of truck and wheel storage in tunnels should be compared with the cost of additional trackage, if sufficient area is available for that trackage at ground level. With any other release track arrangement, a truck must be lowered below an adjoining table top, necessitating a pit depth of approximately 16 to 18 ft, thus increasing the cost of installation.

Necessary for use with the drop table is the body support, either a box girder above the floor, or a box girder below the floor, with only a post-type support above the floor. With drop tables more than 23 ft in length the body support rests should have longitudinal adjustment, as fixed-center rests will result in placing the second truck of certain locomotives on the table top. The investment in the installation of drop-table hoisting equipment and body supports can be justified at those points where major diesel locomotive servicing and repair work are done on enough units to effect savings in labor as well as in the time of returning locomotives to service. At those terminal points where locomotives are only serviced and turned, there may be occasion for truck removal as an emergency measure. At such locations jacks or side release table should be provided for truck removal and repair.

11. Truck Servicing and Repairs

Servicing and repairs to trucks are made in a systematic manner, usually in an area somewhat removed from the area in which the locomotive is serviced. Such an area should be provided with a truck washing platform for cleaning prior to the overhaul. Facilities for steam cleaning and use of detergents should be provided. The truck is dismantled and various pieces of equipment are removed to areas provided for specialized servicing and repair. The traction motors are transferred to the electric shop, air-brake cylinders to the air-brake shop, wheels to the wheel shop; also, wheel truing installations for turning down locomotive wheels without their removal from truck are being used successfully in many shops. Lathe units are also used to mill wheels without removing the trucks from diesels. Many of the truck repair operations can be handled in facilities which may already be available in the railroad terminal.

12. Electrical Shop

Shops should be provided for the servicing of electrical equipment to the extent of disassembling, inspecting, and reassembling traction motors and generators. Special machines in the electrical shop should include a lathe for turning down commutators, baking oven, corn blast cleaning unit, balancing machine, and testing equipment. All cleaning fluid should be of a non-hazardous type with a suggested flash point not lower than that of kerosene. Approved dip tanks and similar accessories should be used to minimize the risk of fire.

13. Engine Repair Shop

The engine repair shop is primarily for dismantling and reassembling engines, which operations are accomplished most satisfactorily in an area separated from the main shop. The room should adjoin an area served by an overhead crane, from which an engine can be set on a "dolly" and wheeled into the engine shop. As the engine work requires the handling of heavy parts, hoisting equipment of adequate capacity is required. A small pit is desirable on each side of the engine assembling track, 2 ft 8 in wide, 2 ft 6 in to 2 ft 9 in deep, and 35 ft long between stairs at each end.

14. Small Parts Reconditioning Shop

The small parts shop should be equipped with valve grinders, resurfacer, grinding and buffing wheels, small press, drill press, small lathe, liner hone, magnaflux machine. magnaglow machine for valves, small monorail hoist for handling heads, work benches. tool cabinets, etc. An adequate number of electric and air outlets should be provided, as well as outlets for oxygen, acetylene and natural gas.

15. Filter and Parts Cleaning Room

It is important that this room, or building, be isolated from other areas, since the steam and moisture from the cleaning tanks is most injurious to finely machined engine and electrical parts exposed in overhaul operation. Ventilating hoods should be placed over the cleaning vats. Walls or ceiling areas exposed to cold temperatures should be insulated to prevent condensation from moisture-laden air. Overhead cranes or hoists should be provided for transferring filters and parts through the various vats, drying ovens, oilers, etc. Attention should be given to providing adequate floor and equipment drainage; that is, carried through an oil separator before discharging in the sewer system. A centrifugal-type filter cleaning unit is recommended as the latest development for considerable space saving and faster cleaning. This machine cleans and re-oils filters of all sizes in one cycle of operation. Portable trucks specially designed for filter accommodation are preferable. Caustic tank should be located outside of the building to permit the removal of grease and paint from the large parts which cannot be accommodated in the parts cleaning shop.

16. Store Room

The store room should be located at elevated platform level to suit incoming deliveries at car-floor height and issued to platforms where many replacements are made. The purchasing and stores division should be consulted as to direct area requirements in this connection.

17. Door Openings

The clear openings of entrance doors should be not less than 14 ft in width and 17 ft in height. Local codes covering clearances are to be followed in determining dimensions.

18. Doors

Doors should be electro-galvanized as well as painted material. They should be easily operated, fit snugly, and be easily repaired and maintained. If overhead steel rolling doors are used, they should be kept painted periodically and should be motor operated. Provision for hand operation should be made in case of power failure or breakdown.

Fire doors on any opening in walls should be so built as to warrant classification as a fire wall.

19. Windows

Windows should be of steel or aluminum, with sash operators.

Glass block should be either light-direction or light-diffusion types.

20. Walls

Walls should be of brick and steel, brick and reinforced concrete, structural steel and insulated (protected metal), cement asbestos, galvanized steel, aluminum or concrete block in combination with reinforced concrete; such walls should be carefully examined to ascertain that all fire requirements are met so as to provide full protection.

21. Roof

Steel purlins with fireproof deck should be used where possible. Built-up roofing should be installed with 20-year bond as required.

22. Heating and Ventilation

The problems involved in heating and ventilating diesel shops are those of removing the exhaust gases from locomotives on test and tune-up, replacing combustion air consumed by the engines with tempered fresh air, and the replacement of heat loss through the building.

At an outlying terminal, where one particular type of diesel locomotive may be housed and serviced, a simple type of telescopic stack fitted with a rain hood or syphon ventilator may be provided for each exhaust port of the locomotive. When engines are to be run while in the house, the stacks are extended to cover the exhaust port, the exhaust having sufficient velocity to expel itself. Unit heaters, generally used for heating such buildings, can be provided with a duct having an outside air intake and adjustable damper for either introducing 100 percent fresh heated air or 100 percent recirculated air.

The problem becomes a challenge in terminal shops where locomotives to be serviced and repaired are of many types and different manufacture. The individual exhaust stack is no longer practical, and the problem is one of providing a mechanical ventilating system. If the overhead crane does not operate in the servicing area in which most engine testing is done, it is possible to provide hoods on the center line of each track and, by means of power exhaust units, collect the gases close to the source and expel them from the building. Another method of providing ventilation in service areas, as well as high crane bay areas, is to install power exhaust units in proper locations throughout the roof deck, and power-driven heater intake units in the wall areas to temper the fresh air and balance the exhaust units. Intake and exhaust units should be as widely separated as practicable to avoid "short circuiting" the fresh air to exhaust units. In connection with the latter, roof areas should be divided into cells by facing one side of roof trusses with asbestos-cement board or sheet metal, the cells confining the gas to an area served by individual exhaust units, permitting operation of individual ventilators as required. In any case, the exhaust gases must be removed before they cool and settle of their own weight.

The heated fresh air supply should be introduced by large units specifically designed for this purpose, and air should be introduced at the lowest point practicable, or, if elevated, the intake air should be deflected by fins downward to aid in the movement of air upward and outward through the roof ventilators. The air supply should be widely distributed at the lowest possible velocity to avoid discomfort to mechanics working on the lower floor and platform levels. Inspection pit heating for employees' comfort and defrosting the undersides of the locomotives is an important consideration.

In addition to fresh air introduced into the building to replace that consumed by engine combustion and exhaust units, space heating units to off-set natural building heat losses must be installed to heat the building when the exhaust supply ventilation system need not be operated.

In some instances continuous exhaust ducts are fitted over each service track, running the full length of the pits, with motors operating exhaust fans installed at 30 to 40-ft centers exhausting through the roof deck. These fans are automatically controlled by thermostats located in the ducts which cut in and out at pre-determined temperature settings. A manual-start one-minute arrangement is also incorporated. Hoods are constructed of asbestos-cement board or sheet metal mounted on a steel frame.

The repair shop is fitted with similar exhaust units mounted on the roof deck without a duct system. They are either manually or automatically controlled as required.

Heating is by a composite system with a forced warm air supplied to service pits, supplemented by unit heaters along the walls of the building and over large doors.

As a result of tests conducted by the U. S. Department of Interior, Bureau of Mines, in the Cascade Tunnel of the Great Northern Railway during October 1944, valuable data were obtained for the calculation ot a diesel shop ventilating system. The diesel locomotive used in the test was an EMD 5400-hp 4-unit freight locomotive, and gas samples of engine exhausts were taken at idling speed (275 rpm), ¾ speed (650 rpm), and full engine speed (800 rpm). The test developed that 0.375 lb of fuel is consumed per hp-hr and 434.4 cu ft of exhaust gas is produced for each pound of fuel consumed. The scavenging and intake air supplied through blowers was 4.27 cfm per hp. Inasmuch as horsepower will vary as the speed, the base horsepower at idling speed (275 rpm) will be 0.344 of full speed (800 rpm) horsepower. Samples of exhaust gases taken at the exhaust outlets developed the following:

	Composition of Samples (Percent of Volume)					
Engine Operaton	*Carbon Dioxide*	*Oxygen*	*Carbon Monox.*	*Hydro-Carbons*	*Nitrogen*	*Oxide of Nitrogen (Parts per Million)*
Full throttle (800 rpm)	6.52	11.93	0.20	0.06	81.29	1117
¾ (650 rpm)	4.52	14.83	0.03	0.00	80.62	936
Idling (275 rpm)	0.68	19.98	0.01	0.00	79.33	145

The following is a typical calculation to determine the building exhaust requirements, similar calculations to be carried out for the maximum number of locomotives which will run in the shop at one time. In idling one 3-unit 6000-hp diesel, the total engine exhaust gases would be

$$\frac{6000 \times 0.375 \times 0.344 \times 434.4}{60} = 5604 \text{ cfm}$$

As the ventilation system must satisfy either code regulations or accepted good practice, consider a typical code requirement which allows 10 percent exhaust gas concentration or 10 parts per million of oxides of nitrogen concentration. To satisfy the limit of 10 percent exhaust gas concentration would require dilution with fresh air of 10 times the exhaust volume, or approximately 56,000 cfm. The governing factor is in reducing the oxides of nitrogen concentration to less than 10 parts per million. From previous exhaust gas analysis we find the existence of 145 parts oxides of nitrogen at idling speed requiring 15 times the volume of fresh air, or approximately 84,000 cfm exhaust.

It will, of course, be necessary to supply heated outside air to supply combustion air, as well as to replace the air exhausted (determined above). The combustion air requirements for the 6000-hp diesel will be as follows:

$$4.27 \times 0.344 \times 6000 = 8808 \text{ cfm}$$

The 84,000 cfm exhaust plus the 8808 cfm air consumed in combustion requires a minimum of 92,000 cfm supply air.

Any method which removes at least a portion of the locomotive exhaust gases from the shop building while they still are in concentrated form, i.e., before they fully disperse into the total volume of air in the shop, will reduce the air changes necessary to keep concentration requirements within recognized limits.

Because of the limited amount of time allowed for the servicing of diesel locomotives, it is not possible to allow engines to cool off, and mechanics working inside a locomotive are often subject to considerable discomfort from engine heat and fumes. Portable fans may be arranged to circulate air through the engine room to provide better working conditions for the maintenance crews.

23. Painting

The diesel locomotive shop permits use of an entirely different color scheme for interior painting than would be considered practical in roundhouses and shops for steam power. For the greatest amount of light reflection, the painting may be of pastel shades consistent with the theory of color dynamics. Hand rails, stairs, crane hooks, and obstructions should be painted bright colors which will be "eye arresting" to the safety hazards which such objects may present. Piping should be painted distinct identifying colors to aid in preventing errors in locomotive servicing or building maintenance operations.

24. Lighting and Electrical Outlets

For servicing and repair shops functioning over a 24-hr period, the best possible artificial lighting system is a requirement of utmost importance. Every diesel shop being of individual design, a report such as this can only suggest methods for artificial lighting and recommend intensities for the various areas of operations.

Recessed waterproof fixtures along the walls of the pits have proved successful in providing illumination for inspection and repair under the locomotive. Lighting intensities of 20 to 30 footcandles are recommended.

Illumination of the sides of the locomotives and areas under the platforms can be effectively done with angle-type fluorescent fixtures, with glass covers to protect against dirt and moisture. Intensities of 30 to 50 footcandles are recommended.

General illumination over the servicing and repair bay areas can be accomplished by high bay incandescent or mercury vapor color-corrected lamps, or a combination of both, sufficient to provide 20 to 30 footcandles intensity. Over the high platforms and special service areas the same type of lighting, with intensities increased to a level of 50 footcandles, is suggested.

Suitable electric outlets of proper phase should be located throughout the inspection pits, servicing and repair areas for extension cords to power tools, steam generator washout machine, vacuum cleaners, welding machines, battery chargers, and other heavy-duty tools.

Circuit breakers should be used in lieu of conventional fuses.

25. Lubricating Oil Supply and Drainage

Proper lubricating oil facilities are an important function of the diesel servicing shop, as they make possible rapid oil changing and normal servicing, with the minimum of expense in handling the oil. Modern oil-handling equipment contributes to keeping the premises clean and minimizes the fire hazards which usually result from old fashioned methods of bulk handling oils. Provision for dispensing lubricating oil should also be made in a heavy repair shop for refilling crank cases of locomotives following repair.

It is customary to keep each refiner's oil separate. This factor necessitates duplication of storage facilities for as many different kinds of oil as are to be used, consisting of storage tanks, pumps, dispensing stations, etc. Storage tanks of such volumes as to permit purchases in tank-car lots are recommended for the larger servicing and repair shops, with pumps of suitable capacity, valved and piped to permit their use in unloading tank cars and for distribution from the storage tank to the dispensing station.

All electrical equipment and motors should be of explosion-proof types, and pumps should be controlled from the unloading and dispensing stations.

Oil dispensing stations located on the elevated platforms consist of separate hose reels for each kind of lubricating oil, with 50 ft of hose. Each dispensing station should be located on approximately 100 ft centers, and the hoses provided with spring loaded nozzles for quick-action control of oil flow. Meters may be provided to measure the quantity of oil used in servicing locomotives. Such a dispensing system is of value in adding small quantities of oil or in making complete oil changes. In some instances lubricating lines require heating.

Oil drainage systems usually consist of a tank placed below the level of the inspection pits with connecting piping from the pits for gravity flow into the tank. Connections should be provided at intervals throughout the length of the pit for making hose connections with the engine drain. The dirty oil is pumped from the gravity storage tank into tank cars and returned to the reclamation plant.

In many instances forced oil drainage systems are preferred and are installed with pumps of suitable capacity; thus storage tanks are kept above floor level.

Portable drain and lubricating oil tanks on wagons of approximately 200-gal capacity should be provided for servicing locomotives in the heavy repair areas not provided with the lubricating oil dispensing and drain oil systems.

26. Water Supply Systems

The recommendations of the Committee on Water, Oil and Sanitation Services, as presented in Chapter 13, should be used as reference in this connection.

27. Related Facilities

As in the case of shop facilities for steam power, the diesel repair shop demands certain related facilities which are vital to efficient operation and power functioning.

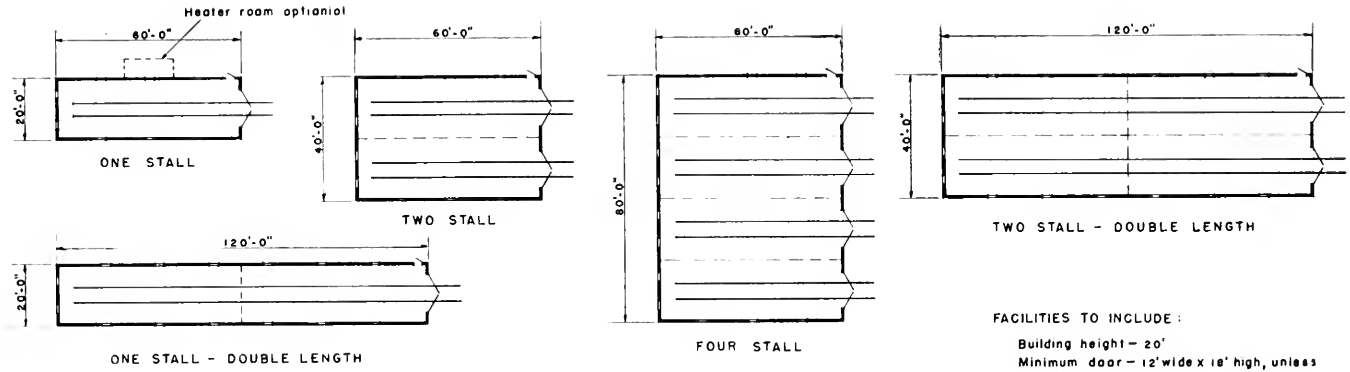
In order that repair parts may be readily available for maintenance, a store room for mechanics and diesel parts should be established as an integral part of the diesel shop facility. As the nature of store stock includes finely machined and finished parts, the construction should be such as to provide a dry, dust-tight, well lighted, ventilated, and temperature-controlled room.

An office area for the use of the diesel shop supervisor and his clerical staff should be located adjacent to the main shop area for proper supervision and the maintaining of servicing records, preferably on the same level as the working platforms.

Adequate locker, lunch, toilet and washing, heating and ventilating facilities should be provided to meet the requirements, and so located as to be as accessible as possible. Individual state codes covering sanitary facilities should govern; however, the suggested approximate minimum requirements for various fixtures are:

One individual water closet	for	every	20	employees	or	fraction	thereof
One individual urinal	"	"	40	"	"	"	"
One lavatory	"	"	10	"	"	"	"
One shower	"	"	20	"	"	"	"

Drinking fountains as required.



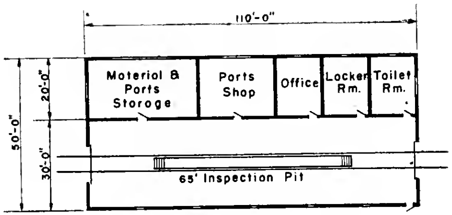
FACILITIES FOR SHORTER INTERVAL SCHEDULED RUNNING MAINTENANCE TO INCLUDE.

- Portable Ramp – Platform height
- Pit – 12' long X 3' deep (minimum)
- Jacking Pads – Two
- Hoist – One one-half ton
- Office – 6' x 8'
- Lavatory and water closet
- Repair Parts

FACILITIES TO INCLUDE:

- Building height – 20'
- Minimum door – 12' wide x 18' high, unless specified by state.
- Heat – To hold building at 60° or above
- Lighting – Overhead reflector units, receptacles and power outlet.
- Compressed air
- Hose bibs
- Roof ventilators

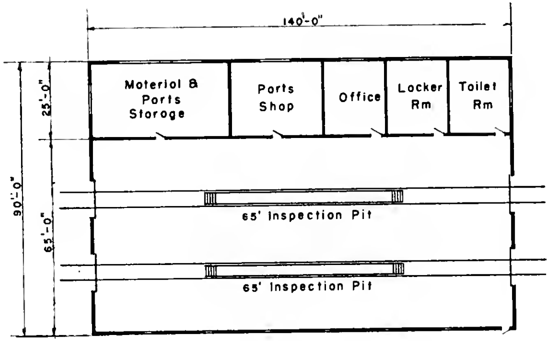
ROAD SWITCHER SHELTER HOUSES FOR OVERNIGHT OR WEEK-END STORAGE



TEN OR LESS LOCOMOTIVES

FACILITIES TO INCLUDE:

Sectionol or continuous jocking blocks
Crane – 20 ton, 30' lift from top of rail and minimum 25' runwoy.
Portoble steps ond plotforms (depressed floors ond plotforms optionol)
Roof ventilotors
Lube oil storoge ond piping system (optionol)
Rolling steel doors

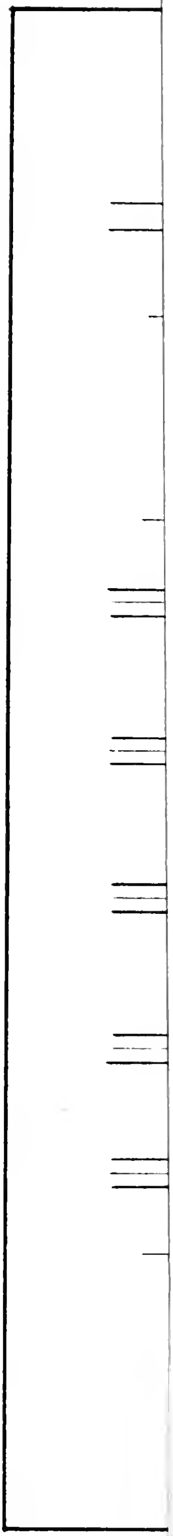


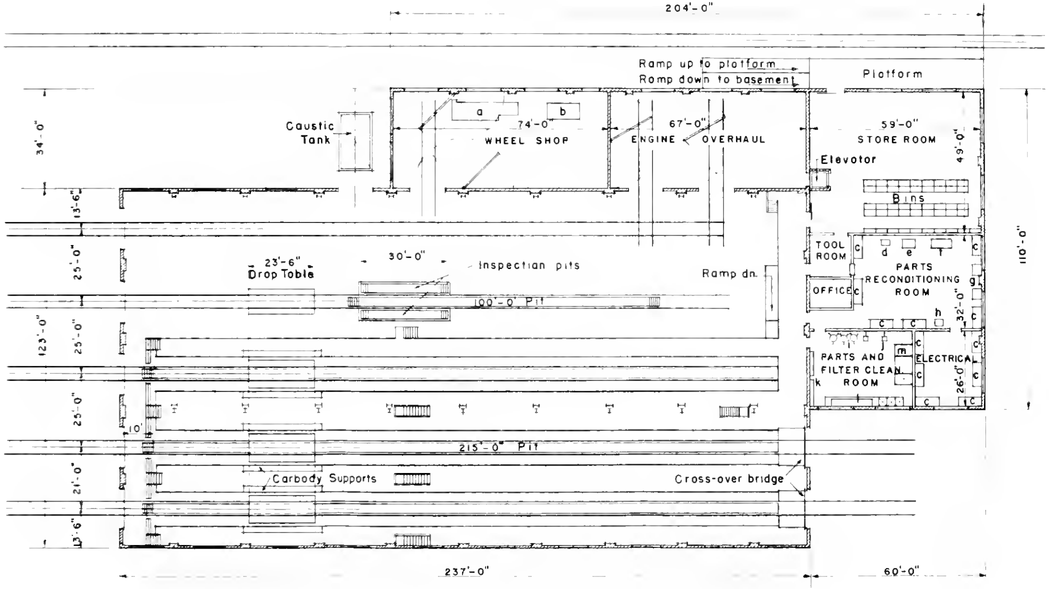
TEN TO TWENTY LOCOMOTIVES

FACILITIES TO INCLUDE:

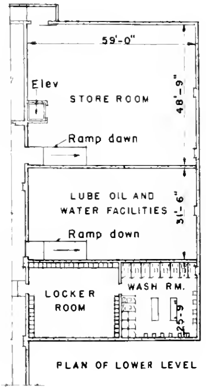
Jocking blocks
Crone – 30 or 40 – ton, 30' lift from top of roil ond runwoy full length of building.
Portoble steps ond plotforms (depressed floors ond plotforms optionol)
Roof ventilotors
Lube oil storoge ond piping system (optionol)
Rolling steel doors

SHOP FACILITIES FOR TWENTY OR LESS LOCOMOTIVES



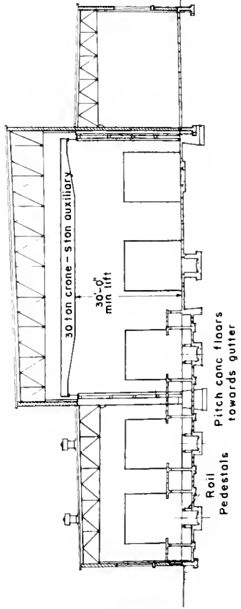


FLOOR PLAN OF HEAVY AND RUNNING REPAIR SHOP FOR DIESEL LOCOMOTIVES



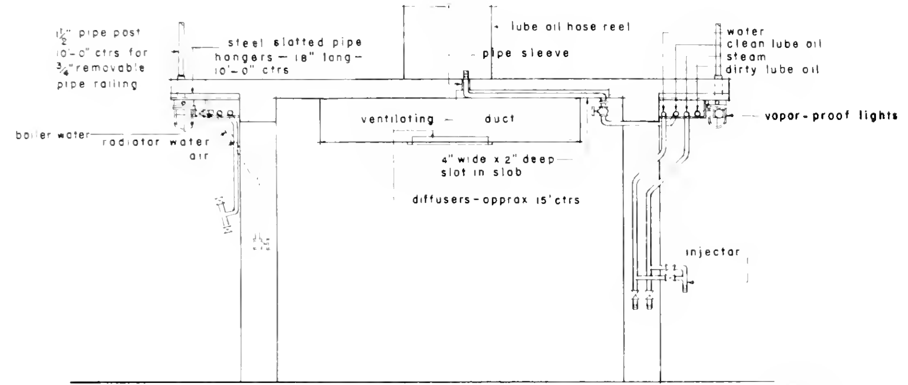
PLAN OF LOWER LEVEL

a - wheel lathe
b - lathe
c - bench
d - drill press
e - press
f - lathe
g - head and valve tools
h - grinder
i - filter pkg. racks
j - liner hone
k - filter storage
l - air filter cleaning equipment
m - cleaning tank

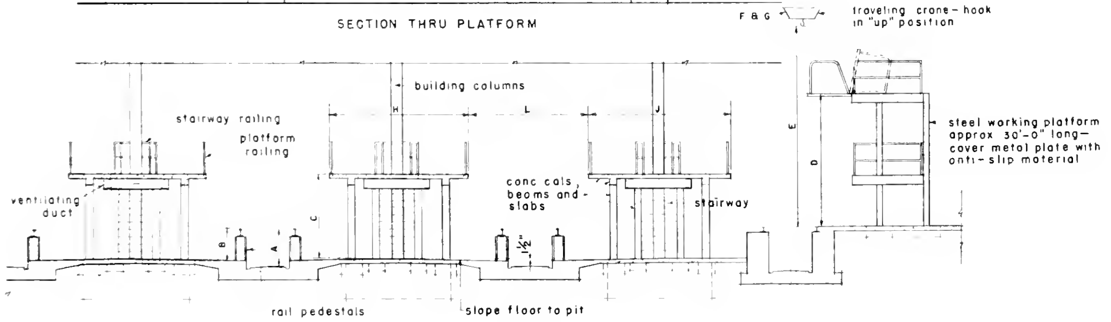


SECTION A-A

HEAVY REPAIR SHOP FOR DIESEL LOCOMOTIVES



SECTION THRU PLATFORM



SECTION THRU PITS IN HEAVY AND RUNNING REPAIR SHOP FOR DIESEL LOCOMOTIVES

Letter Iden.	Dimensions				Description
	Running Maintenance		Heavy Repairs		
	max	min.	max	min.	
A	4'-6"	4'-0"	4'-6"	4'-0"	Pit to rail level
B	2'-10½"	2'-5"	2'-10½"	2'-6"	Lower floor to rail
C	7'-6"	7'-2"	7'-6"	7'-2"	Lower floor to low level pfm
D	14'-8"	13'-4½"	14'-6"	13'-9"	Rail to high level pfm.
E	36'-0"	21'-0"	33'-0"	29'-3"	Rail to crane hook in "up" position
F	30 T	1 T	35 T	30 T	Main hoist capacity-tons
G	—	—	5 T	5 T	Auxiliary hoist capacity-tons
H	13'-0"	6'-9"	14'-0"	12'-0"	Width of low platform
J	14'-0"	8'-4"	12'-0"	12'-0"	Width of low platform
K					Width of high platform
L	30'-6"	11'-0"	11'-0"	11'-0"	Distance between low platforms
M	28'-0"	20'-0"	36'-0"	23'-0"	Distance ℄ to ℄ adjacent pits
N	28'-0"	23'-8"	32'-0"	28'-0"	Distance ℄ to ℄ adjacent pits
O	44'-0"	10'-0"			120 volt receptacles
P	60'-0"	20'-0"			3 phase power
Q	72'-0"	25'-0"			Clean lube oil outlets
R	72'-0"	25'-0"			Dirty lube oil drains
S	72'-0"	25'-0"			Treated radiator water
T	100-0"	50'-0"			Air
U	75'-0"	50'-0"			Boiler water
V	75'-0"	50'-0"			Welding
W					Drinking

Bibliography of Selected Articles on Shop Facilities for Diesel Locomotives

The following bibliography of material pertaining to shop facilities for diesel locomotives is presented as information:

Railway Age

How the B&O Centralizes Freight Diesel Repairs	Dec.	1952
Biggest Diesel Shop in Canada	Dec.	1952
Diesels Take Over Another Steam Facility	Nov.	1952
Heavy Maintenance Work on 192 Diesels	May	1952
Shops and Equipment	Jan.	1953
DSS&A Adds Diesel Shop to Engine House	Jan.	1953
Using Standardized Buildings for Diesel Shops	Mar.	1953
Diesels are Effectively Serviced in Converted Roundhouses	Nov.	1953
Katy Converts Two Steam Shops for Diesel Shops	June	1953
$90,000 Diesel Shop for the TP&MP	Nov.	1953
Ontario Northern Builds Diesel Shop of Latest Design	Nov.	1953
New S.A.L. Terminal at Savannah	Nov.	1953
Diesel Shops of Latest Design	Nov.	1953
Here is an All Purpose Electric Shop	Dec.	1953
Grinder Used to Maintain Wheels	Dec.	1953
New Rock Island Diesel Shop	Dec.	1953
Survey of Repair Shops for Diesel-Electric Locomotives	Copyright	1953

Railway Locomotives and Cars

The C&O Diesel Shop at Huntington	Jan.	1953
B&O Changes Glenwood Shop	Jan.	1953
N.P. South Tacoma Electric Shop	Jan.	1953
Diesel Shop Problems	Feb.	1953
Diesel Locomotive Cleaning Arrangement	March	1953
High Production Air Filter Cleaning	March	1953
Santa Fe Extends Shop	April	1953
Drop Pit with Traction Motor Guide	May	1953
Roundhouses Can Still be Useful	June	1953
Diesel Shop Ideas	July	1953
Report on Diesel Shop Repairs	Aug.	1953
Santa Fe's Diesel Motive Power	Aug.	1953
Seaboard Has Model Motor Shop	Sept.	1953
Diesel Shop Pattern is Slowly Taking Shape	Oct.	1953
M–K–T Converts WACO Back Shops	Oct.	1953
I.H.B. Converts Gibson Terminal for Diesel Work	Nov.	1953
Truck Disassembled in 30 Minutes	Nov.	1953
Katy Converts to Diesels	Dec.	1953

1953 Pre Convention Report—Locomotive Maintenance Officers Association

Report of Committee on Diesel Shop Practices	Page	75
Report of Committee on Diesel Shop Planning	Page	119

Association of American Railroads, Operations and Maintenance Department, Electrical Section of the Engineering and Mechanical Divisions

Repair Shops, Layover Facilities Outlying Points, Annual Report Committee 12	Page 75	1954
For 10 or less and 20 or less units—AAR—ES 1953	Page 337	

Modern Railroads

Re-Group and Centralize Shops	May	1951
Service Diesels for High Availability	May	1951

Rock Island Centralizes Diesel Repairs	June	1951
Special Statistics Evaluate Diesels	July	1951
C&EI Performance Improved by Dieselization	July	1951
T.P.&W. Builds a New Tradition	Sept.	1951
Diesel Locomotive Specifications	Oct.	1951
Converts to Diesels	Nov.	1951
From Mule Teams to Diesels	Dec.	1951
Overhaul Diesels in Record Time	Jan.	1952
San Bernardino "Keeps 'Em Moving"	Jan.	1952
Shop Ingeunity Does Its Part Too	Jan.	1952
Diesels Haul 35 Percent of W.M.s Freight	May	1952
Progressive Dieselization Under Way	July	1952
Diesel Locomotive Specifications	Sept.	1952
NYC Dieselizes	Sept.	1952
Meet Challenge of Dieselization	Oct.	1952
Half Million Horsepower in Diesels	Oct.	1952
Barstow Grows with Dieselization	Nov.	1952
Mo.Pac. Dieselizes K.C. Shops	Dec.	1952
B.&O. Glenwood Diesel Shop	Jan.	1953
ACL Modernizes a Busy Terminal	Mar.	1953
Keep Time Sheets on Diesels	April	1953
A Dieselized Southern Streamlines Facilities	April	1953
W.P. Streamlines Diesel Servicing	June	1953
Material Control Cuts In—Shop Time of S.P. Diesels	June	1953
Diesel Survey	June	1953
U.P. Completes Largest Diesel Repair Terminal	July	1953
Wabash Prepares for Diesel Era	Aug.	1953
Diesel Locomotive Specifications	Sept.	1953
New Phase of Dieselization	Sept.	1953
Periodic Maintenance Keeps Diesels Rolling	Dec.	1953
New Era for Santa Fe Shops	Dec.	1953
Motive Power—Cars—Shops	Jan.	1954
Now An Ultra-Modern Railroad Electric Shop	Feb.	1954
Coast Line Develops Production Shops	May	1954

Report on Assignment 4

Wind Loading for Railway Building Structures

C. E. Defendorf (chairman, subcommittee), J. S. Cooper, L. B. Curtiss, T. J. Engle, W. G. Harding, J. W. Hayes, K. E. Hornung, I. A. Moore, G. A. Morison, B. M. Murdoch, J. T. Rowan, A. B. Ryan, J. B. Schaub, J. J. Schnebelen, J. T. Schoener, E. R. Shultz, J. W. Wagner, O. G. Wilbur, T. S. Williams.

Your committee, endeavoring to develop specific wind loading recommendations for inclusion in the Manual, has been studying the problem of minimum requirements for wind loads with the National Bureau of Standards, and has concluded that the recommendations of the American Standards Association for minimum wind loads are acceptable.

The report of Subcommittee 1—Revision of Manual, includes the necessary changes to be made in the Manual.

Report on Assignment 9

Air Conditioning

Collaborating with Electrical Section, AAR, Committee 12

J. W. Gwyn (chairman, subcommittee), C. M. Angel, W. F. Armstrong, C. E. Booth, T. S. Carter, D. W. Converse, L. A. Durham, Jr., V. E. Elshoff, C. S. Graves, J. F. Hendrickson, K. E. Hornung, B. J. Johnson, Jr., Earl Kimmel, L. H. Laffoley, N. C. LeClaire, G. A. Morison, W. C. Oest, J. T. Rowan, A. B. Ryan, J. T. Schoener, B. M. Stephens, S. G. Urban, T. S. Williams.

Your committee submits as information the following final report, supplementing the report in the Proceedings, Vol. 54, 1953, page 610.

Air Conditioning of Railroad Office Buildings

Any information for railroad professional engineers with respect to methods of air conditioning railroad office buildings should necessarily be very general. For a project of this size, the final design and construction supervision should be under the direction of a competent heating and ventilating specialist.

The following discussion does not cover every method of air conditioning a railroad office building, but it dces outline a variety of ways that a given building (or buildings) might be air conditioned. Economic, esthetic and operational considerations will govern the final choice of air conditioning, but the following description of various air conditioning methods may prove helpful in a preliminary selection of equipment.

1. Direct Expansion Mechanical Refrigeration

The most common source of cooling is by means of direct expansion mechanical refrigeration. For air conditioning a large building four general variations of direct expansion refrigeration are used.

a. *Zoned Distribution of Air*

This method requires two air distribution systems, generally running in adjacent ductwork: one for refrigerated air and one for recirculated air. Mixing dampers are located at strategic locations—each to serve a small portion of the building (referred to as a zone). Each mixing damper is controlled by a thermostat which may function by either electricity or compressed air.

This double system of air trunk ducts, plus the necessary power to overcome high air friction of long duct runs, may make such a system expensive to install and operate. However, when a building with an unused stairway or elevator shaft is under consideration for air conditioning, this system can prove economical by enabling both the cold and warm air duct to run from floor to floor through the big vertical shaft. Unused large salvage blower fans from dismantled roundhouse heating systems may be well utilized thus to keep construction costs down.

b. *Distributed Refrigerant Under Pressure*

This widely used method of air conditioning confines compressor and condenser equipment to a conveniently isolated spot, such as a basement. A freon-type refrigerant is distributed to fan and direct cooling coil stations throughout the building. Circulation of air around the coils is constant, and by thermostatic control at the expansion valve admitting refrigerant to the coils, room temperature is regulated. Refrigerant pressure remains constant.

If interior appearance of the building is important, refrigerant piping probably must be concealed; and concealed refrigerant piping which may be also inaccessible, in turn, creates a bad maintenance problem. Small leaks from freon refrigerant piping may quickly liberate an expensive refrigerant charge, yet the leak may be detected only by a laborious "soap bubble test" or a "Halide torch" which burns with a green flame in the presence of freon. Nevertheless, when copper lines can be made impervious to refrigerant and can be protected from abuse and building settlement, a very satisfactory air conditioning system may result.

c. *Water-Cooled "Package-Type" Air Conditioning Units*

This type of air conditioning can be best described as dividing a building in two or more independent air conditioning systems, each consisting of 15 tons or less. This method of air conditioning is currently popular because of the economies inherent in the mass-produced "package units." Minimum installation labor is required, depending upon reduced ductwork requirements.

The biggest disadvantage of a multiple installation of package-type units comes from the cooling water problem. In order not to waste cooling water continuously, a piped supply and return system must be run between package units, a water pump and cooling tower. As the number of package units becomes great, the cost of condenser water piping approaches that of a chilled water distribution system.

Another disadvantage of multiple package-type air conditioning units comes from their high resulting noise level, particularly from the 10 and 15-ton units. If it is required that offices be very quiet, package-type air conditioning units must be installed in small rooms or closets—at a sacrifice in floor space and money.

Nevertheless, a multiple installation of package-type air conditioners is very often the most feasible method of air conditioning.

d. *Window-Type Air Conditioners*

This method of air conditioning eliminates all piping and ductwork but requires the maximum possible number of air conditioning units. In a large installation this is the ultimate in creating a big number of air conditioning zones, but comfortwise, maximum zoning is not most effective.

On an original price basis, window-type air conditioning units are seldom excelled, but on a maintenance basis their cost is high. Since these units are made to meet a price on a highly competitive home market basis, their quality and stamina is lowest.

Since this type of unit must be mounted in a window opening to provide access to outside air for the condensers, such installations often disfigure the outside appearance of a building.

Air distribution within a room can be difficult with window-type conditioning units. Since the units usually fit about 3 ft from the floor, cold air must necessarily be directed upward to avoid drafts. Thus it may become impossible to give air a "throw" to direct cooling of a remote portion of the room.

Nevertheless, window air conditioning units are useful for minimum cost installations and for installations where cooling water is not available. Future development and research may possibly improve the window conditioner to a point where its performance compares more favorably with the larger units.

2. Indirect Mechanical Refrigeration

With indirect mechanical refrigeration, cooling is accomplished by circulation of a chilled liquid such as water. The liquid is generally chilled close to the compressor, and the cooling coils are located at remote points.

Circulation of chilled liquid is generally constant, and control of room temperature is through face and by-pass dampers at each cooling coil. Modulating dampers to by-pass any required proportion of the air around the cooling coil afford a very satisfactory control of room temperature. Operation of blower fans is also nearly constant.

Indirect refrigeration for air conditioning is usually more expensive to install than direct expansion cooling, but as the design cooling load approaches 200 or 300 tons, the costs tend to equalize.

Except for its frequently higher initial cost, indirect refrigeration overcomes most of the disadvantages of direct refrigeration. By remote location of refrigeration machinery, noise can virtually be eliminated, and insulated chilled water piping is much more dependable than refrigerant piping, since there is less chance for loss of expensive refrigerant and no necessity for long runs piped in copper.

3. Cooling by Chilled Water from Natural Sources

Lest some diligent designer comes up with a premature idea for a mechanical refrigeration system, mention is hereby made of cooling from natural sources.

Underground springs and wells with water colder than 52 deg F may be known to exist near the building to be cooled. Such a source of chilled water in sufficient gallonage may well provide a quick solution for the design of an air conditioning system. Care must be taken, however, to ascertain the hardness of such spring water and to install the necessary treatment if required. Mineral-encrusted cooling coils become most inefficient.

Proximity of large bodies of cold water, such as streams and lakes, may afford a supply of chilled water for an air conditioning system, and their potentialities should not be neglected. Ocean water is difficult to use in small diameter cooling coils because of salt encrustation and its corrosive action.

If an available source of water is not sufficiently cold—though plentiful—provision may be made to utilize this water for cooling condensers in lieu of a cooling tower or evaporative condenser. Water hardness must, in this case, also receive due consideration.

4. Evaporative Cooling

The earlier forms of air conditioning consisted of evaporative cooling. This evaporative cooling took two forms: The passage of air through an open spray of water and air passing through a loosely packed, water-saturated material. This same principle is regularly used to dissipate heat from both evaporative condensers and cooling towers.

Briefly stated, the principle is that, air, in taking up water vapor, loses "sensible heat." This possible drop in temperature is proportionate to the dryness of the surrounding air.

In desert localities such as Arizona and Nevada, air is so dry that it may become cooler than 65 deg before saturation is reached. In such dry places, mechanical refrigeration is not necessary for air conditioning and evaporative cooling directly performs the cooling function very well.

5. Steam-Jet Vacuum Cooling

Steam-jet cooling in unusual instances may have a useful application in the railroad office building field, but little equipment of this type has been made in recent years because of high operational costs.

This system depends upon chilled water produced by creating a vacuum in a partially filled tank of water. As the pressure of the atmosphere is reduced, a low boiling point is reached, causing loss of heat as the water vaporizes. A steam jet maintains this vacuum in the chilled water tank, and it is the resulting steam wastage from this jet which makes for excessive cost of operation.

If there is a source of cheap steam available to a railroad office building, or even better, a regular demand for large quantities of heated water, steam-jet vacuum cooling can prove to be economical. Conceivably, some sort of a manufacturing or boiler washout plant near a railroad office building might, by contracting for great quantities of exhaust steam, bear enough of the fuel costs to make steam-jet cooling financially attractive.

6. Absorption Cooling

This is the operating principle which makes a well known gas refrigerator function and it has the advantage of no moving parts or resulting noise. Cooling is obtained from a heat-transfer process accomplished under two different stages of high vacuum.

A solution of lithium bromide and water is heated while under a pressure of about 1/15th of an atmosphere, and much of the water distills off and is condensed while the resulting concentrated chemical solution overflows and is utilized, as will be presently mentioned. The condensed water vapor becomes the refrigerant which passes to expansion coils under a vacuum of about 1/75th of an atmosphere and flashes into vapor in the presence of the heat to be extracted. The water vapor then flows to the absorber where it is quickly taken up by the concentrated lithium bromide solution having a great affinity for water.

Equipment of this type is made in package units of the 2, 3.3 and 5.4-ton capacities with provision for winter space heating included in all units.

A 25-ton package unit is also made, and this unit is generally used for the circulated chilled water (indirect) type of air conditioning. It is recommended for multiple use when refrigeration loads exceeding 25 tons occur.

On all types of absorption refrigeration for air conditioning, a supply of cooling water is required from a cooling tower or on a wastage basis.

The biggest disadvantage of this kind of refrigeration is its high initial cost, especially in regard to the 25-ton units which require an outside source of steam. Cost of producing this steam during the cooling season may exceed comparable electric power charges. The local cost of natural gas is also a determining factor in the use of the smaller, direct-fired, package units.

Report of Committee 30—Impact and Bridge Stresses

E. S. Birkenwald, *Chairman,*
E. R. Andrlik
D. S. Bechly
J. H. Brown
E. E. Burch
A. B. Chapman
Abram Clark
F. H. Cramer
C. P. Cummins
A. C. Danks, Jr.
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A. R. Harris
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E. A. Johnson
Frank Kerekes
W. B. Kuersteiner
A. N. Laird
C. T. G. Looney
C. V. Lund
J. F. Marsh
J. P. Michalos
D. W. Musser
C. H. Newlin
N. M. Newmark
M. J. Plumb, *Vice Chairman,*
E. W. Prentiss
H. C. Prince
C. A. Roberts
J. H. Shieber
C. E. Sloan
C. B. Smith
R. L. Stevens
J. P. Walton
E. Wollett, Jr.
J. D. Woodward
L. T. Wyly

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Viaduct columns, collaborating with Committee 15.
No report.

2. Steel girder spans with open decks and with ballasted decks.
Progress report, presented as information .... page 450

3. Dynamic shear in girder and truss spans.
Progress report, presented as information .... page 450

4. Impact and bending stresses in columns and hangers of truss spans.
No report.

5. Concrete structures, collaborating with Committee 8.
Progress report, presented as information .... page 450

6. Determination of braking and traction forces in bridge structures, collaborating with Committees 7, 8 and 15.
Progress report, presented as information .... page 451

7. Stresses and impacts in timber stringer bridges, collaborating with Committee 7.
Progress in study, but no report.

8. Steel truss spans with open decks and with ballasted decks.
Progress report, presented as information .... page 451

9. Distribution of live load in bridge floors:
(a) floors consisting of transverse beams;
(b) floors consisting of longitudinal beams.
Progress report, presented as information .... page 451

10. Stresses in lateral bracing of bridges.

Progress report, presented as information .... page 452

THE COMMITTEE ON IMPACT AND BRIDGE STRESSES,
E. S. BIRKENWALD, *Chairman*.

AREA Bulletin 519, December 1954.

Report on Assignment 2

Steel Girder Spans with Open Decks and with Ballasted Decks

M. J. Plumb (chairman, subcommittee), E. R. Andrlik, D. S. Bechly, E. E. Burch, F. H. Cramer, C. P. Cummins, A. C. Danks, Jr., A. T. Granger, A. R. Harris, Frank Kerekes, C. T. G. Looney, J. F. Marsh, J. P. Michalos, D. W. Musser, N. M. Newmark, H. C. Prince, C. E. Sloan, C. B. Smith, J. P. Walton, J. D. Woodward.

As part of a continuing study of impact and stresses in steel girder spans, a report will be published during 1955 giving results of tests on eight bridges on the Chicago, Milwaukee, St. Paul and Pacific Railroad.

Tests have been completed on a girder span on the Atchison, Topeka and Santa Fe Railway, at the request of Committee 15, to determine whether cover plates of girders having as much as 75 percent of the flange area in cover plates are effective in resisting bending moment.

Report on Assignment 3

Dynamic Shear in Girder and Truss Spans

(For subcommittee, see report on Assignment 2)

A report on this assignment is included in the report of tests on eight girder spans on the Milwaukee Road, to be published under Assignment 2.

Report on Assignment 5

Concrete Structures

Collaborating with Committee 8

J. H. Shieber (chairman, subcommittee), Abram Clark, J. A. Erskine, R. R. Gunderson, R. H. Heinlen, W. B. Kuersteiner, A. N. Laird, J. P. Michalos, E. W. Prentiss, C. A. Roberts.

Last year your committee presented as information a report covering the laboratory tests of a number of full-size reinforced concrete bridge slabs designed by various theories, one of which was a prestressed, pretensioned slab designed for Cooper E 72 loading in accordance with present recommended practice.

As a result of the successful behavior of this prestressed slab under static load, two additional prestressed slabs, which were manufactured at the same time, were placed in a Chicago, Burlington & Quincy Railroad bridge in high-speed territory last March for the purpose of field testing them under actual operating conditions at various speeds.

Because of existing slow orders over adjacent bridges, however, these field tests have been postponed until the spring of 1955.

These tests will be conducted by the AAR research staff, and a final report will be issued after all of the data taken in the field have been fully analyzed.

Report on Assignment 6

Determination of Braking and Traction Forces in Bridge Structures

Collaborating with Committees 7, 8 and 15

(For subcommittee, see report on Assignment 2)

A report of tests on a New York, Chicago and St. Louis Railroad bridge at Fillmore, Ill., was presented in AREA Bulletin 516, June–July 1954, page 1. Determination of stresses resulting from longitudinal forces showed that most of the longitudinal forces on this structure were being taken by the rails to the roadbed behind the abutments.

This report also presented the results of tests on short-span wide-flange beams and on concrete-filled steel pipe piles. The results of the tests on the beams verified the conclusions drawn from previous tests on similar spans with elastic supports. The tests of the piles gave the first information obtained by your committee on this particular type of construction.

Report on Assignment 8

Steel Truss Spans with Open Decks and with Ballasted Decks

(For subcommittee, see report on Assignment 2)

Tests were made during 1954 on a bascule bridge in Detroit, Mich., at the request and expense of the Detroit, Toledo & Ironton Railroad, to determine if the bridge was capable of carrying heavily loaded ladle cars.

Tests were also made on a 288-ft 9-in draw span across the Illinois River at Meredosia, Ill., at the request and expense of the Wabash Railroad, to determine the load-carrying capacity of the bridge.

Report on Assignment 9

Distribution of Live Load in Bridge Floors

(a) Floors consisting of transverse beams;
(b) Floors consisting of longitudinal beams

(For subcommittee, see report on Assignment 2)

A report on transverse and longitudinal distribution of locomotive axle loads on bridge floors was presented in AREA Bulletin 516, June–July 1954, page 45. The report includes data on nine bridges obtained from both steam and diesel locomotives operating at a wide range of speeds.

Report on Assignment 10

Stresses in Lateral Bracing of Bridges

(For subcommittee, see report on Assignment 2)

A report on this assignment is included in the report of tests on eight girder spans on the Milwaukee Road, to be published under Assignment 2.

Report of Committee 22—Economics of Railway Labor

R. J. Gammie, *Chairman,*
Lem Adams (E)
A. D. Alderson
M. B. Allen
H. C. Archibald
B. V. Bodie
W. H. Brameld (E)
E. J. Brown
J. A. Bunjer
R. H. Carpenter
G. E. Chambers
A. B. Chaney
P. A. Cosgrove
C. G. Davis
M. H. Dick
W. W. Edwards
J. E. Eisemann
H. J. Fast
J. L. Fergus
C. G. Grove
W. H. Hamilton
K. H. Hanger

L. C. Gilbert, *Secretary,*
E. B. Harris
G. L. Harris
W. W. Hay
W. H. Hoar
G. W. Hunt
T. B. Hutcheson
Claude Johnston
H. W. Kellogg
G. A. Kellow
N. M. Kelly
W. I. King
H. E. Kirby
L. A. Loggins
Roy Lumpkin
T. E. MacMannis
J. S. McBride (E)
J. F. McCook
E. H. McIlheran
W. H. Miesse
H. C. Minteer
C. R. Montgomery

D. E. Rudisill,
Vice Chairman,
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R. W. Pember
J. A. Pollard
R. R. Pregnall, Jr.
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R. B. Radkey
C. W. Reeve
M. S. Reid
L. H. Rose
R. R. Smith
J. S. Snyder
A. Tagliafer
P. V. Thelander
W. H. Vance (E)
H. J. Wecchetder
H. M. Williamson
F. R. Woolford
C. R. Wright

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Analysis of operations of railways that have substantially reduced the cost of labor required in maintenance of way work.

   Progress report, presented as information .... page 455

3. Economies in railway labor to be derived from the use of various types of ballast, collaborating with Committee 1.

   Final report, presented as information .... page 460

5. Labor economy of renewing ties by use of proper equipment, methods and organization.

   Progress report, presented as information .... page 465

6. Labor economies of various mechanical methods of tamping and equalizing ballast, including the double shifting of machines.

   Progress report, presented as information .... page 467

7. Comparative economy of handling maintenance of way gangs in trucks versus motor cars, including economical length of haul, collaborating with the Purchases and Stores Division, AAR.

   No report.

8. Means of increasing or conserving labor supply for the duration of the emergency, advising the secretary currently of recommendations or practices that merit emergency publication by the AREA.

No report.

THE COMMITTEE ON ECONOMICS OF RAILWAY LABOR,
R. J. GAMMIE, *Chairman.*

AREA Bulletin 519, December 1954.

MEMOIR

Charles William Baldridge

A man who was symbolic of all the loyal, conscientious and hard-working members of the American Railway Engineering Association passed away on May 31, 1954, at Chicago. He was Charles William Baldridge who retired in 1942 as assistant engineer on the Atchison, Topeka & Santa Fe Railway. Mr. Baldridge had joined the AREA on January 9, 1916, and served on various committees. His longest term of service was with Committee 22—Economics of Railway Labor, of which he was a member for 15 years. At the annual meetings of the Association Mr. Baldridge was an active participant in discussions of committee reports from the convention floor. Following his retirement from railroad service in 1942 he became a Life Member of the Association.

Mr. Baldridge was born in Woodford County, Ill., on April 18, 1869. He obtained his higher education at Baker University and at the University of Kansas, studying electrical and civil engineering. He entered railroad service in 1896 with the Kansas City, Watkins & Gulf (now part of the Missouri Pacific). Subsequently he served with the Santa Fe from 1897 to 1898, with the Chicago, Burlington & Quincy in 1899, with the Kansas City, Ft. Scott & Gulf (now part of the Frisco) from 1900 to 1901, with the Chicago & North Western from 1902 to 1906, with the Saratoga & Encampment (now part of the Union Pacific) in 1907, with the North Western from 1908 to 1910, with the Rock Island in 1911, and with the Santa Fe from 1912 until his retirement.

As assistant engineer on the Santa Fe, Mr. Baldridge became an authority on all matters pertaining to rail. It was his responsibility to keep a record of all rail in track and to make periodic inspections of rail to determine its condition and to make recommendations to the chief engineer regarding the need or advisability of renewal. If difficulties arose with particular heats of rail, it was his assignment to determine the cause of the trouble and to advise what steps should be taken. He also took part in matters involving the design of rail, and consulted frequently with metallurgists identified with rail mills.

As a committee member in the AREA, Mr. Baldridge contributed unstintingly of his knowledge and experience. His record of committee service is as follows: Committee 2—Ballast, from 1916 to 1924; Committee 1—Roadway, from 1925 to 1934 (he served as vice chairman of this committee in 1927 and as its chairman from 1928 to 1933); the Special Committee on Clearances, from 1927 to 1933; Committee 22—Economics of Railway Labor, from 1933 to 1948; and Committee 5—Track, from 1935 to 1943.

Mr. Baldridge was also active in the affairs of the Roadmasters' and Maintenance of Way Association, serving as president of that association in 1934-1935.

M. H. DICK, *Chairman,*
J. S. MCBRIDE,
G. M. O'ROURKE,
Committee on Memoir.

Report on Assignment 2

Analysis of Operations of Railways that Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work

J. E. Eisemann (chairman, subcommittee), Lem Adams, M. B. Allen, H. C. Archibald, B. V. Bodie, W. H. Brameld, E. J. Brown, G. E. Chambers, W. W. Edwards, C. G. Grove, W. H. Hamilton, K. H. Hanger, E. B. Harris, G. L. Harris, W. W. Hay, T. B. Hutcheson, Claude Johnston, H. W. Kellogg, G. A. Kellow, H. E. Kirby, E. H. McIlheran, T. E. McMannis, H. C. Minteer, C. R. Montgomery, G. M. O'Rourke, J. A. Pollard, C. W. Reeve, M. S. Reid, L. H. Rose, J. S. Snyder, A. Tagliafer, P. V. Thelander, W. H. Vance, F. R. Woolford.

Submitted as information, this is the thirteenth report of a series on this subject, which has been reassigned annually since 1935. The current study covers a reorganized and comprehensive system of track and roadway maintenance on the Chesapeake and Ohio Railway, previous studies having dealt with various maintenance operations on the Lehigh Valley; Norfolk & Western; St. Louis–Southwestern; Great Northern; Illinois Central; Denver & Rio Grande Western; Delaware & Hudson; Delaware, Lackawanna & Western; Pennsylvania; Elgin, Joliet & Eastern; St. Louis–San Francisco; and Atchison, Topeka & Santa Fe railroads.

In addition to statistical data, the committee members and guests were given a most profitable and pleasant trip over a representative part of the Chesapeake District of the Chesapeake and Ohio System. This trip provided excellent means, through a special roadway inspection car, for first-hand observation of the property traversed, and of the distribution of the forces engaged in the work program. This roadway inspection car was, in itself, of much more than casual interest. Providing an accurate and continuous graphic record of joint condition, alinement, cross level and surface, the inspection car is operated at 6-month intervals, and performs a definite service in the track maintenance program.

The Chesapeake District, as herein referred to, was the area encompassed at the time programming and scheduling were initiated in their present comprehensive detail. This area included the territory now known as the Southern Region, as well as that part of the Northern Region known as the Hocking Division.

The Chesapeake District of the Chesapeake and Ohio is primarily a double-track railroad, with some short stretches of third and fourth track at points of highest traffic density. Apart from jointly operated tracks, it has a total trackage of 6023 miles to maintain, divided as follows:

Miles of road	2,811.98
Miles of second main	809.37
Miles of third main	44.32
Miles of fourth main	7.36
Miles of yards and sidings	2,350.40
Total	6,023.43

Speed of trains generally is limited to 75 mph in passenger service and to 55 mph in freight service, with reductions to 60 and 40 mph, respectively, in mountainous and heavily curved territories.

Main line track construction consists, for the major part, of 132-lb rail, except for 5 subdivisions on which 115-lb rail is used, with 6-hole headfree rail joints, double-shoulder tie plates 7¾ by 14¾ in, except that tie plates 8 by 18 in are used on curves of 3 deg or more. The minor part is laid with 131-lb rail on 7¾ by 13-in tie plates. Treated mixed oak ties of grades 4 and 5 are used in main track, and are spaced on 21-in centers. Principal main lines are ballasted with crushed limestone and slag, although some subdivisions are still ballasted with prepared gravel, which includes a minimum of 40 percent crushed gravel and ranges in size from 1½ in to No. 10. Other ballast is required not to exceed 1½ in nor to be less than ½ in. Anchor spikes, 4 per tie, are used on all curves of 2 deg or more.

The 2812 miles of road operated as the Chesapeake District is divided for maintenance purposes into 9 divisions. Reference to Table 1 will indicate the comparative numbers and length of sections and the section and extra force personnel prior to and following the rearrangement as established for the Chesapeake District. It will be noted that sections were reduced from 457 to 281 in number, or 39 percent, and that main track mileage per section was increased 64 percent, from an average of 8.6 miles to 14.1 miles. In terms of personnel, there was an average of 2844 trackmen, exclusive of supervision, required prior to the rearrangement, as compared with a total of 1525 trackmen afterward, a reduction of 46 percent. The bulk of this decrease was in section men, average numbers of whom were, respectively, 2011 and 843, a reduction of 58 percent. For extra forces the average numbers were 833 and 682, respectively, or a decrease of 18 percent.

At about the time of adoption of the present comprehensive system of programming and scheduling work, the Chesapeake and Ohio supplemented its labor-saving equipment by the addition of power units for tamping, jacking, gaging, tie drilling, ballast regulating, ballast cleaning, track cleaning, and bolt wrenching. The phrase "tie drilling" refers to the Chesapeake and Ohio practice of drilling $\frac{9}{16}$-in holes for the application of spikes as a part of the new rail laying operation.

Under the present system, which has been in effect since the fall of 1952, all heavy out-of-face maintenance work is performed by extra forces. Personnel, equipment and materials are allotted in accordance with the size and time schedule of the job, with due allowance for various factors affecting the work. The work of section forces consists mainly of spotting, opening drainage facilities, policing and miscellaneous.

Out-of-face track surfacing, with which most of the maintenance program is coordinated, is usually scheduled over a 7-month period beginning April 1. Principal deviation may be the laying of new rail, which is handled by a system force; this work is programmed and performed at any time, except the most severe winter period, as the most advantageous circumstances may indicate. The interval of the out-of-face track surfacing cycle is from 3 to 5 years on practically all main lines. Ties are renewed at the time the track is surfaced, and the usual track lift averages 2 in. Traffic is detoured around the work so far as practicable, and at some locations temporary crossovers have been installed for this purpose.

The entire track and roadway maintenance program for the following year is prepared in the early fall, complete in detail and on the most realistic basis. After approval, the program book is published and distributed to all having responsibility for executing the program. The work contemplated on each division is set up in the program book, loose pages from which are distributed on divisions to local supervisors, thus serving as work sheets. The program book covers in detail the mile post limits to tenths of each individual lot (shortest segment of the project) of work, the time schedule of the work —beginning and ending dates—quantities and kinds of materials required, number and types of machines to be assigned, and in some instances the quantities and kinds of materials released.

TABLE 1

THE CHESAPEAKE AND OHIO RAILWAY COMPANY
CHESAPEAKE DISTRICT
DISTRIBUTION OF FORCES BEFORE AND AFTER
REORGANIZATION AND SECTION REARRANGEMENT

DISTRICTS	Miles Main Track	Sections Total No.		Main Track Miles Avg. Per Section		Laborers Per Sec.		No. Extra Forces No.Ex.Fc.Laborers	
		Before Reorg.**	After Reorg.**	Before Reorg.*	After Reorg.*	Before Reorg.	After Reorg.	Before Reorg.	After Reorg.
N.N. & N.T.	16.1	6	4	8.1	16.1	6.5	3.0	1 - 15	1 - 13
Peninsula	141.6	15	9	9.4	15.7	4.3	3.0	1 - 25	1 - 60
Piedmont	136.9	18	10	8.1	13.7	3.7	3.0	1 - 25	1 - 15
Rivanna	159.8	23	14	6.9	11.4	4.2	3.0	1 - 25	
RICHMOND DIVISION	454.4	62	37	8.0	13.4	4.3	3.0	4 - 90	3 - 88
James River	169.4	22	13	8.1	13.0	4.4	3.0	1 - 26	1 - 21
Mountain	100.7	15	10	7.2	11.2	4.3	3.3	1 - 14	1 - 14
Alleghany	177.1	22	11	8.1	16.1	4.3	3.2	3 - 25	1 - 58
Greenbrier	97.9	5	5	19.6	19.6	3.0	2.0		
CLIFTON FORGE DIVISION	545.1	64	39	8.8	14.3	4.2	3.0	5 - 115	3 - 93
New River	150.2	21	13	7.5	12.5	4.5	3.3	3 - 25	1 - 58
Piney	70.7	11	8	7.1	10.1	3.5	2.5		1 - 10
New River Brs.	84.5	11	7	7.7	12.1	3.5	2.6		1 - 10
HINTON DIVISION	305.4	43	28	7.4	11.7	4.0	2.9	3 - 75	3 - 78
Charleston	136.1	17	9	8.0	15.1	5.5	3.0	3 - 25	1 - 7
Huntington	93.7	13	9	7.8	10.4	4.7	3.0	2 - 25	(1 - 58
Cabin Creek	82.4	7	7	11.8	11.8	4.9	3.0		(2 - 7
Coal River	153.7	19	12	8.1	12.8	3.6	3.0	1 - 12	1 - 14
Barboursville	108.8	12	6	9.1	18.1	5.0	3.0	1 - 25	1 - 17
Logan	110.5	15	10	7.9	11.1	4.4	3.0	1 - 11	1 - 7
HUNTINGTON DIVISION	685.2	83	53	8.5	12.9	4.6	3.0	8 - 173	7 - 110
Paintsville	111.3	14	8	8.0	13.9	4.6	3.3	1 - 18	1 - 25
Martin	105.0	14	6	7.5	17.5	3.9	3.2	1 - 18	1 - 12
Shelby	125.1	14	8	8.9	15.6	3.9	2.6	1 - 18	
Lexington	125.1	19	10	6.6	12.5	3.8	3.0	1 - 18	1 - 25
ASHLAND DIVISION	466.5	61	32	7.6	14.6	4.0	3.0	4 - 72	3 - 62
RUSSELL DIVISION	19.4	5	4	9.7	19.4	7.2	3.0	1 - 15	1 - 13
Ohio River	133.2	13	7	10.2	19.0	4.5	3.1	1 - 25	1 - 14
Cincinnati	120.4	12	6	10.0	20.1	4.1	3.2	1 - 25	1 - 14
Cinc. Term.	42.7	7	6	6.1	7.1	3.7	2.5	1 - 12	1 - 10
Northern	183.0	18	10	10.2	18.3	5.4	3.1	3 - 25	1 - 58
CINCINNATI DIVISION	479.3	50	29	9.6	16.5	4.6	3.0	6 - 87	4 - 96
Maumee	50.6	11	8	8.4	12.7	5.5	3.0	1 - 25	1 - 10
Marion	144.3	19	9	7.6	16.0	4.8	3.0	2 - 25	(1 - 58
Cols. Terminal	95.4	14	12	8.7	9.5	5.8	3.0	2 - 23	(1 - 10
Pomeroy	262.8	10	10	26.3	26.3	4.4	3.0		
HOCKING DIVISION	553.1	54	39	12.0	16.8	5.1	3.0	5 - 121	3 - 78
Miami	72.7	11	6	6.6	12.1	3.9	3.0	1 - 25	1 - 14
Middle	78.1	11	6	7.1	13.0	3.9	3.0	1 - 25	1 - 25
Wabash	95.4	13	8	7.3	11.9	4.2	3.0	1 - 35	1 - 25
CHICAGO DIVISION	246.2	35	20	7.0	12.3	4.0	3.0	3 - 85	3 - 64
SYSTEM TOTAL	3754.6	457	281	8.6	14.1	4.4	3.0	39-833	30-682

* Exclusively yard sections omitted
** Includes yard sections

TABLE 2

THE CHESAPEAKE AND OHIO RAILWAY COMPANY

CHESAPEAKE DISTRICT

COMPARATIVE TRAFFIC AND M. OF WAY DATA

YEAR	TOTAL GROSS TON MILES (000's)	AVERAGE AGE RAIL RELEASED FROM FIRST LOCATION	LABOR - ROADWAY & TRACK	
			MAN-HOURS	MAN-HOURS PER 000,000. GTM
1930	-	7.34	-	-
1931	43,243,574.	7.74	-	-
1932	36,193,978.	7.57	-	-
1933	38,920,264.	7.94	-	-
1934	40,821,569.	7.62	-	-
1935	40,453,160.	8.57	-	-
1936	47,014,636.	8.90	-	-
1937	45,912,951.	10.10	-	-
1938	38,246,737.	9.70	6,922,097	181.0
1939	42,230,390.	10.70	7,100,284	168.1
1940	46,983,020.	10.92	7,474,742	159.1
1941	51,405,678.	10.74	8,274,682	161.0
1942	58,032,898.	11.75	9,173,351	158.1
1943	62,238,620.	12.76	10,365,527	166.5
1944	64,940,608.	12.70	11,206,336	172.6
1945	62,285,748.	13.00	10,950,847	175.8
1946	59,659,086.	12.20	9,430,856	158.1
1947	73,145,435.	13.10	11,381,337	155.6
1948	68,251,775.	13.40	10,491,900	153.7
1949	51,037,374.	13.00	8,453,052	165.6
1950	57,615,410.	14.10	7,541,810	130.9
1951	68,015,329.	14.88	8,009,370	117.8
1952	60,689,000.	13.60	7,639,149	125.9
1953	54,178,699.	14.31	6,927,340	127.9
1954	-	12.83	-	-

The program, which is rigidly followed, covers full personnel of assigned forces, the forces being identified by code numbers, and the following work: new rail laying; relay rail laying; turnout renewals; other track materials; main track tie renewals; side track tie renewals; switch tie renewals; ballast allotments; track stabilization; tamping schedules; shoulder ballast cleaning with two off-track machines; shoulder and center ditch ballast cleaning, under contract, by on-track machine; bolt tightening; track cleaning; and chemical weed and brush control.

The original application of programming, including certain basic changes as to division of work between small and large forces, cycles of renewals, and many others, produced quite satisfactory results and justified the decision to expand the plan to the entire system.

TABLE 3

THE CHESAPEAKE AND OHIO RAILWAY COMPANY

REPORT COMPARING CERTAIN TRACK WORK MAN HOURS

CHESAPEAKE DISTRICT

	PROGRAM 1954	1953	1952	1951	1950	1949	1948
Track Surfacing							
Track Miles	739.2	916.9	1109.9	1160.8	860.8	1090.2	1067.5
Man Hours (000's)	864.0	1202.4	1463.3	1476.5	1135.4	1436.3	1442.4
Mn.Hrs./Mile	1169.	1311.	1318.	1272.	1319.	1318.	1351.
Ties - Main Line							
No. Renewed (000's)	311.5	466.0	495.1	463.8	396.2	399.9	423.0
Man Hours (000's)	190.0	298.8	312.7	284.0	283.3	287.3	321.4
Mn.Hrs./Tie	0.61	0.64	0.63	0.61	0.72	0.72	0.76
New Rail							
Trk. Miles Laid	193.2	196.8	140.3	204.7	204.4	178.0	232.5
Mn.Hrs.Layg. (000's)	251.0	269.8	192.7	328.5	283.6	284.5	465.7
Mn.Hrs./Mile	1300.	1371.	1373.	1605.	1387.	1599.	2003.
New Rail - Unloading Mn.Hrs./Mile	208.	208.	202.	208.	195.	228.	Incl.
							Under
New Rail - Load Old Mn.Hrs./Mile	107.	107.	108.	119.	113.	136.	Laying

Reference to Table 2, showing total roadway and track man-hours, indicates the trend of the relationship of maintenance and use over a 16-year period on the Chesapeake District of the Chesapeake and Ohio. Maintenance is expressed in man-hours, and gross ton miles is taken as an index of the use of the property.

Table 3 indicates the general decline in cost of performing certain track maintenance jobs in terms of man-hours per mile or per unit. These are significant figures, because the value of any system of organizing forces is measured by the amount of work accomplished and the elements of its quality and comparative cost in terms of man-hours.

Important as a factor of saving in the overall economy is the Chesapeake and Ohio practice of maximum utilization of its investment in modern maintenance machinery. This effect is supplemented by the judicious use of the labor necessary for full and continuous production. Collateral advantages include the use of off-track transportation of the forces to the extent practicable, and the housing of men in well-equipped modern camp cars.

Conclusion

The Chesapeake and Ohio has been able to reduce the labor required in maintaining its track and roadway by:

1. Reorganizing its forces on a realistic basis.
2. Carefully planning and programming its operations.
3. Intensive use of labor-saving machinery.
4. Efficient and constructive use of labor.
5. Detouring traffic around work operations so far as practicable.

Report on Assignment 3

Economics in Railway Labor to be Derived From the Use of Various Types of Ballast

A. B. Chaney (chairman, subcommittee), Lem Adams, M. B. Allen, W. H. Brameld, E. J. Brown, J. A. Bunjer, R. H. Carpenter, P. A. Cosgrove, C. G. Davis, M. H. Dick, W. W. Edwards, J. L. Fergus, L. C. Gilbert, W. H. Hamilton, K. H. Hanger, E. B. Harris, W. W. Hay, G. W. Hunt, T. B. Hutcheson, N. M. Kelly, W. I. King, G. M. O'Rourke, R. W. Pember, L. F. Racine, C. W. Reeve, M. S. Reid, R. R. Smith, J. S. Snyder, A. Tagliafer, W. H. Vance, F. R. Woolford.

This is a final report, submitted as information.

From replies to a questionnaire prepared in November 1953, your committee has assembled information received from 40 railroads, representing 175,623 miles of road. While the actual comparative cost data were less than desired, the following summary of replies reflects the experience and judgement of engineering and maintenance-of-way officers on 65 percent of the mileage of railroads in the United States and Canada:

1. *Types and sizes of ballast used. (In order of preference).*

Table 1 shows preferences as to types of ballast presently used and emphasizes the importance given to crushed slag and stone, as well as to the decrease in use of gravel ballast when compared to data of 10 to 20 years ago.

Table 2 presents preferences as to sizes used and shows a marked trend to the smaller materials when compared with similar information reported by this committee in the Proceedings, Vol. 39, 1938, page 595.

2. *Preferences as to principal qualities, shape and grading of ballast particles.*

Angular to cubical.
Sharpness.
Minimum percentage of voids.
Graded uniformly as to size.
Give good bond and compaction.
Free of smooth edges and thin elongated pieces.

3. *Value of hardness factor and maximum loss permitted in the Los Angeles abrasion test.*

All roads value the hardness factor and state that ballast materials should be hard enough to resist pulverizing under the action of traffic and tamping. Fifteen roads reported maximum losses permitted under Los Angeles abrasion tests as follows:

20—1 road
25—1 road
30—4 roads
35—2 roads
40—7 roads
—
15 roads

TABLE 1—SUMMARY OF REPLIES TO QUESTIONNAIRES

Types of Ballast Used (In Order of Preference)

Kind of Ballast	*A* *First Preference*			*B* *Second Preference*			*C* *Third Preference*		
	Number Railroads Reporting	*Total Miles of Road*	*Percent of Total*	*Number Railroads Reporting*	*Total Miles of Road*	*Percent of Total*	*Number Railroads Reporting*	*Total Miles of Road*	*Percent of Total*
Crushed slag	15	79,338	45.2	4	15,241	8.7	4	23,152	13.2
Crushed stone	12	66,929	38.1	9	77,759	44.3	3	25,225	14.4
Crushed limestone	7	8,654	4.9	5	18,032	10.3	4	10,629	6.0
Chat	3	15,779	9.0	9	44,419	25.3	3	14,395	8.2
*Gravel	3	4,923	2.8	8	12,007	6.8	12	79,915	45.5
Cinders				2	745	0.4			
No preference stated				3	7,420	4.2	14	22,277	12.7
Total	40	175,623	100.0	40	175,623	100.0	40	175,623	100.0

*Crushed and washed.

TABLE 2—BALLAST SIZES USED

Number of Railroads	*Maximum Size*	*Number of Railroads*	*Minimum Size*
3	2½"	5	1"
8	2"	13	¾"
23	1½"	1	⅝"
3	1¼"	4	½"
1	¾"	4	⅜"
		3	¼"
2	No Report	10	No Report
40		40	

4. *Value of friction developed between ballast and ties.*

Twenty-eight roads consider the friction factor important while three did not. The greater the friction developed the less labor is required to maintain line and surface; greater friction also provides increased anchorage and more uniform load distribution.

5. *Reasons for using the various sizes of ballast.*

The principal reasons given are listed below:

Availability and cost.

Small sizes more economical for tamping light raises.

Compacts—remains undisturbed.

Develops friction—holds line and surface better.

Large sizes for flood territory and to reduce loss in ballast cleaning operations.

Better walking surface.

6. *What type of ballast is most economical and suitable where power tampers are used.*

Thirty-one roads expressed a preference for crushed stone and slag (max 1½ in), while three preferred coarse chat (max ¾ in and 1¼ in).

7. *Value of weathering factor.*

Next to hardness, most roads considered the weathering factor important, especially in those regions where freezing temperatures are expected. The sodium sulphate soundness test, with a weighted average of not to exceed 10 percent after 5 cycles, is favored.

8. *Frequency of reballasting.*

Twenty-nine roads reported that the use of the A-type ballast extended the cycle of reballasting by an average of 20 percent as compared to B-type ballast.

Eight roads reported a 33 percent increase in their reballasting interval with A-type ballast as compared to gravel.

9. *Labor of reballasting.*

Replies from 28 roads indicated little, if any, difference in the amount of labor required for reballasting with A and B types of ballast. The exception was that chat required 15 to 20 percent less labor for this operation than for other types of ballast.

10. *Labor of renewing ties.*

Thirty-three roads indicated that labor of renewing ties averaged 4 percent less in B-type ballast as compared to A-type materials, with an average further reduction in this item of 15 to 25 percent in chat ballast.

11. *Labor for smoothing and lining track.*

Information furnished from 30 roads indicated that labor for smoothing and lining averaged 12 percent less for A-type as compared to B-type ballast.

12. *Labor keeping down vegetation.*

A summary of data from 27 roads indicated little difference in the cost of this item for A and B types of ballast. This is accounted for largely by the extensive use of chemicals for vegetation control. Users of chat reported that most classes of this material control vegetation growth to a greater extent than other types of ballast.

13. *Rail anchorage—type of ballast.*

Replies from 8 roads developed that it required 25 percent more anchors in gravel and fine ballast to develop equal holding power to crushed limestone, stone and slag ballast.

Nineteen roads did not think any change in the number of anchors necessary on account of the various types of ballast used on their lines.

14. *Unloading ballast.*

Replies indicated that some soft ballast materials, such as cinders, rock screenings and fine chats, cost two to three times as much to unload as coarser materials like slag, rock and gravel.

15. *Effect of type of ballast on cross tie life.*

Seventeen roads reported no effect. Five estimated five years less life in gravel and cinders than in crushed limestone. Three expressed the belief that ties would give five years more service in crushed slag than in chats.

16. *Ballast required per mile per year.*

Fourteen roads report no difference in the amount of ballast required per mile per year due to different types of material. Eight roads estimated that 25 percent less of A-type ballast was required as compared to their second preference or B-type material.

17. *Comparative costs of maintaining track on various types of ballast.*

Comments from six roads are listed below:

Labor cost more where limestone and gravel are used as compared to chat.

Labor cost index—slag 0.95; rock 1.00; gravel 1.30.

Labor cost index—chat 884; rock 1000; gravel 9975.

Cinders—most expensive ballast.

For heavy traffic, stone and slag will cost less per year.

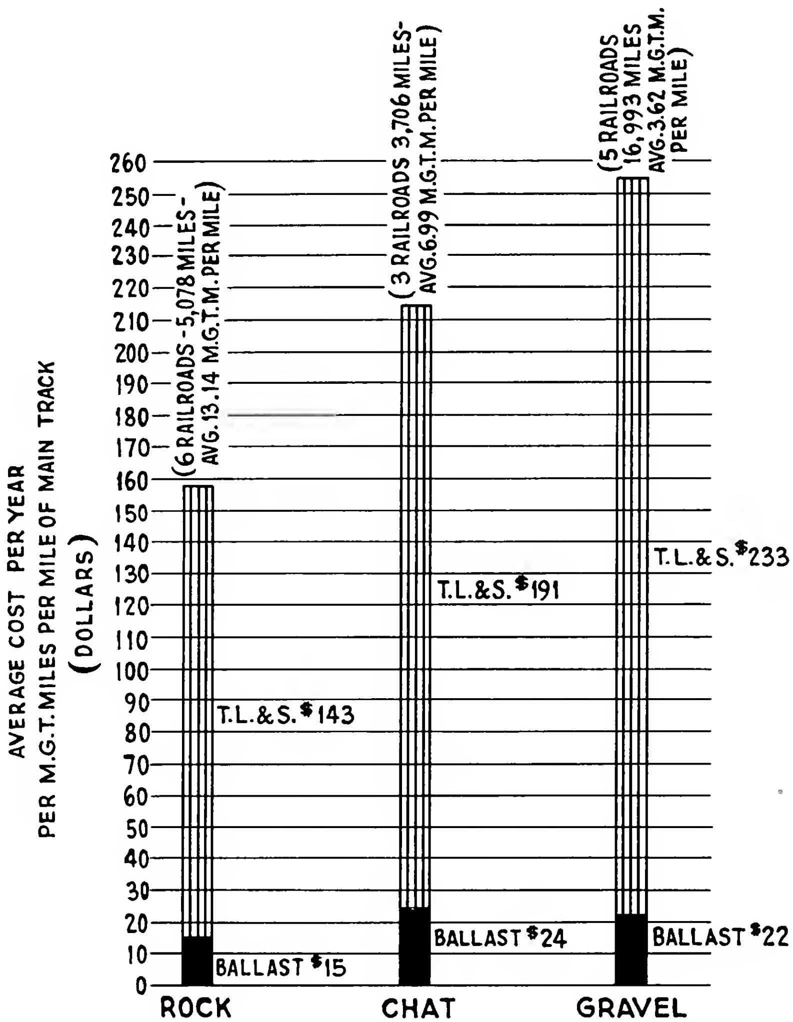
In gravel ballast, labor costs average 33 percent higher than where crushed limestone is used.

* * *

Nine roads furnished cost data for ballast and track labor accounts 218 and 220, as well as tonnage covering a 10-year period for territories where the type of ballast used remained substantially the same (75 percent or more) during that time. For purposes of comparing this information with chat and gravel lines, crushed slag and stone were considered in the same class. While only 25,777 miles of main tracks were included in this study, the 9 roads represent widely separated locations and diverse conditions.

Exhibit "A" shows the average annual cost per million gross ton miles per mile of main track for:

EXHIBIT A



COST PER YEAR OF BALLAST MATERIAL AND TRACK LAYING AND SURFACING
PER MILLION GROSS TON MILES PER MILE OF MAIN TRACK
10 YEAR AVERAGES - 1943-1952 OR 1944 - 1953
DATA FROM
25,777 MILES OF MAIN TRACK ON 9 RAILROADS

a. Ballast. (Account 218).
b. Track Laying and Surfacing. (Account 220).

It is recognized that density of traffic is only one important factor in the amount of ballast and track labor required; also, these figures represent only the lines reporting for the particular period and can only be accepted as a guide in preparing similar studies covering other lines and periods.

Conclusions

For heavy and medium-heavy-traffic lines, crushed stone and slag ballast meeting AREA specifications, with maximum size of 1½ in and uniformly graded, is the preference of most railroads, based on overall economic consideration.

For medium and light-traffic lines, chat, and in some cases crushed gravel, are the most economical ballast materials.

Except for special requirements, most roads prefer ballast materials for general use within a size range of from ½ in to 1½ in.

Definite economies in railway labor can be derived by using the most suitable types of ballast, and it is believed that individual roads can profit from a study of the subject on the basis of factors existing on their lines.

Report on Assignment 5

Labor Economy of Renewing Ties by Use of Proper Equipment, Methods and Organization

L. A. Loggins (chairman, subcommittee), H. C. Archibald, E. J. Brown, J. A. Bunjer, R. H. Carpenter, P. A. Cosgrove, C. G. Davis, M. H. Dick, J. E. Eisemann, H. J. Fast, J. L. Fergus, L. C. Gilbert, W. H. Hoar, Claude Johnston, N. M. Kelly, W. I. King, Roy Lumpkin, J. F. McCook, E. H. McIlheran, T. E. MacMannis, W. H. Miesse, H. C. Minteer, J. P. Morrissey, R. W. Pember, J. A. Pollard, R. R. Pregnall, Jr., L. F. Racine, R. B. Radkey, L. H. Rose, D. E. Rudisill, R. R. Smith, P. V. Thelander, H. J. Weccheider, H. M. Williamson, F. R. Woolford, C. R. Wright.

Your committee submits the following report of progress in the study of methods, equipment and organization used in the replacement of track ties. A previous report on this subject may be found in the Proceedings, Vol. 55, 1954, pages 531 and 532.

Thirty-two railroads furnished information outlining the methods, equipment and organization used to replace ties. All of these roads use section gangs to replace ties. Twenty-seven use extra gangs in addition when making renewals incident to out-of-face resurfacing work. Six roads—the Atchison, Topeka & Santa Fe, Boston & Maine, Nashville, Chattanooga & St. Louis, New York Central System, and the Southern Pacific Lines in Texas and Louisiana—also use special gangs organized for the purpose to renew some of their ties.

On practically all of these railroads ties are inspected and marked to be replaced, by section foremen and either roadmasters or track supervisors, and, in most cases, they are also checked by other officers. On the Illinois Central an experienced maintenance-of-way employee, having specialized tie knowledge and accompanied by a section foreman or supervisor of track, makes inspections and marks ties to be replaced. On the Santa Fe a tie department inspector inspects and marks those ties which are to be renewed by the tie gangs and resurfacing gangs, but the section foremen and roadmasters inspect and mark those to be renewed by others.

On most of the railroads reporting, ties are handled to the job site by work train or local freight when available. Otherwise they are unloaded at stations or sidings and later distributed by track car. Ties are loaded loose and are unloaded by hand, except on four roads where some ties are banded and handled with cranes. All report the use of gondola cars, but some also use flat, box and stock cars to some extent. Special tie cars are used on the Santa Fe, New York Central and Western Pacific, and it is believed that, after further study and improvement, the use of special tie cars will produce substantial savings.

The reports indicate substantial savings to be made by unloading ties from work train or local freight at the job site, instead of unloading at stations or sidings and later distributing them by track car.

The use of specially organized and equipped tie gangs on six railroads indicates the following percentages of reduction in cost from the conventional method with hand tools:

Santa Fe	58
B&M	42
NYC—(Comparative data not furnished)	
Southern	67
SP in Texas & Louisiana	22

The Santa Fe and B&M gangs are equipped with more mechanical tools and produce greater savings than the partially mechanized gangs on other railroads. NC&StL tie gangs use only hand tools but show substantial savings over the use of ordinary section gangs with hand tools, because it has been found that gangs which perform tie renewals every day become more skilled and adept at it than those used only periodically for the purpose.

The Delaware, Lackawanna & Western handles tie renewals on a cycle basis and uses a highly mechanized 70-man gang for heavy main-line tie replacements in connection with raising and resurfacing track. This gang averages resurfacing 120 rails per day with tie replacements averaging 700 per day. The practice of the DL&W is to remove all ties which will not last 6 or 7 years, and many of the recovered ties are used in yard tracks. The roadmasters or supervisors mark the ties to be replaced. The ties are loaded loose in drop-end gondola cars, are delivered to the job by work train, and are unloaded with a tractor crane. Old ties are picked up in the same manner.

This study indicates that substantial economies are to be gained by the use of properly organized and equipped gangs to renew ties. It is believed that other railroads will adopt the use of special tie gangs for renewing some of their ties, and that ideas for special tie-handling cars will be developed. It is recommended that this subject be continued.

Report on Assignment 6

Labor Economies of Various Mechanical Methods of Tamping and Equalizing Ballast, Including the Double Shifting of Machines

Claude Johnston (chairman, subcommittee), A. D. Alderson, B. V. Bodie, R. H. Carpenter, G. E. Chambers, A. B. Chaney, C. G. Davis, J. E. Eisemann, H. J. Fast, J. L. Fergus, G. L. Harris, W. H. Hoar, G. W. Hunt, H. W. Kellogg, W. I. King, L. A. Loggins, J. S. McBride, J. F. McCook, T. E MacMannis, W. H. Miesse, C. R. Montgomery, J. P. Morrissey, J. A. Pollard, R. R. Pregnall, Jr., R. B. Radkey, C. W. Reeve, M. S. Reid, D. E. Rudisill, W. H. Vance, H. J. Weccheider, H. M. Williamson, C. R. Wright.

Your committee submits the following report of progress in studies made of the economies of various methods of mechanical tamping and equalizing ballast. For the purpose of this report, a power tamper is defined as an on-track machine with power-operated and controlled tamping mechanism.

While the committee has not previously reported in detail on this subject, it is mentioned in the Proceedings, Vol. 53, 1952, page 355, in the report on Labor Economies of Various Methods of Tamping Track. This report compared the relative advantages of power-tamped track to track tamped by hand, and pointed out that the savings to be derived from power tampers were in direct proportion to their availability and allowable working time.

As the basis of our current report, a questionnaire was prepared and sent to 59 railroads. This questionnaire requested information on the number and kind of power tampers in use, class of track worked, size of gang, and raise recommended for each type of machine. The railroads were also asked to state the average production and number of hours of working time per day.

Types of Machines

Replies to the questionnaire were received from 48 railroads. Of these only 4 indicated that they did not own power tampers. However, 2 of these railroads had used them on a rental basis.

A total of 425 power tampers were reported in use by 44 railroads. These were listed according to their manufacturer as follows: Type A, 167; type B, 64; type C, 61; type D, 12; type not specified, 119 (this group included 1 or more of types listed above).

One railroad is using 2 machines made in its own shops. Only 2 railroads reported using all 4 types. One of these has 61 machines in service. Six railroads stated that they had 20 or more power tampers in operation.

Scope of Use

All railroads reported that the principal use of power tampers was for out-of-face surfacing or raising main-line track. However, 27 railroads use the machines on branch-line or secondary class tracks for out-of-face surfacing operations, and 20 railroads use them for spot work and smoothing. Thirty-six railroads indicated that tampers were operated under traffic on double track, and 28 railroads stated that the detour method was used on double track.

Only seven railroads reported that they were required to use train crews or conductor-pilots to furnish flag protection for tampers. Most of these stated that the use of transportation department crews did increase the cost of operation, but not to an extent that would curtail or prohibit use of power tampers. Only one railroad stated that the presence of train crews resulted in increased production.

Maintenance

All railroads reported that preventive maintenance was a daily task of the tamper operator. This included lubrication, which was the most important feature mentioned in answer to the question covering preventive maintenance.

All railroads maintain an adequate supply of spare repair parts. This stock is based on manufacturers' recommendations as well as experience of the railroads in operating the tampers. Only six railroads stated that a repairman was kept on duty full time with a tamper during operation. The remainder of the railroads reporting stated that division mechanics and maintainers were available on short call when needed for emergency repairs. Periodic field inspections were made by division, as well as system, equipment maintainers. General overhaul is done by some railroads during winter months when machines are not operating. One southeastern railroad makes a practice of exchanging principal operating units of type C machine on a cycle basis, in the field, during week-ends when the gangs are off duty. Compressors, power units and tamping units are then given a general overhaul in the shop and returned to the next machine in cycle.

A high degree of availability was reported for all four types of machines. No attempt was made to analyze maintenance costs for any type of machine.

Methods of Operation

The number of hours per day that power tampers were worked varied from 3½ to 6, with most railroads reporting an average of 5 hr.

The maximum track raise recommended by railroads reporting varied from 1½ to 10 in. The maximum size of ballast being used was 2½ in. There was a wide variety of track raises suggested as the best general practice; however, raises from 1½ to 3 in were most reported.

Eighteen railroads reported that the type of machine controlled or influenced the minimum raise, but no specific trend of this influence could be attributed to any particular type of machine in use. All but six railroads reported that the size of ballast controlled the minimum raise, and these railroads generally suggested a maximum raise of over 6 in. Machine-type C, was recommended for the lowest raise, this being from 0 to ¾ in.

Reports on the average footage tamped per day, including track lining, varied from 1250 to 4000 ft where tampers were used as single units. Average daily production for 2 machines operated in tandem ranged from 2000 to 5400 ft.

The sizes of gangs used with power tampers varied from 4 to 45 laborers for single-unit operation, and from 22 to 70 laborers for tandem operation.

Twenty-seven railroads indicated that ties were installed during surfacing operation with tampers, and 10 railroads reported that gangs varying from 8 to 20 laborers, in addition to a surfacing gang, were used for lining and follow-up operation. Five railroads reported that lining was done with a machine, using from 3 to 5 laborers.

Twenty-two railroads stated that road crossings and switches were brought to final surface during the surfacing operation.

Most railroads reported that no figures were available as to the cost per foot for surfacing with power tampers. Several railroads reported essentially the same amount of track surfaced in equal periods of time and under the same general conditions as to installation of ties and surfacing through grade crossings.

Most railroads arranged to unload ballast ahead of the surfacing operation, and all but three of the railroads reporting used some type of machine to equalize the ballast section after the tamping operation. Approximately one-half of the railroads do some preparatory regulating or equalizing before tamping, in addition to equalizing after surfacing is completed.

No report was made on double shifting of machines, as only one railroad was known to have developed this practice to any great extent, and the committee feels that this portion of the assignment can be covered at a later date.

Conclusion

The use of power tampers has resulted in substantial savings, not only in productive time but also in the uniform compaction of ballast under the ties, which results in longer intervals between out-of-face surfacing raises.

The extent to which the potential economies of a power tamper can be realized is a problem for each individual railroad. Since this machine is essentially a labor-saving device, the extent to which gangs can be reduced and still maintain production under varying local conditions is a direct measure of the labor economies of the power tamper.

Although this study is incomplete, it indicates that substantial economies can be gained by using power tampers. It is recommended that the study be continued.

Report of Committee 3—Ties

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Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress report, submitted as information .... page 472

2. Extent of adherence to specifications.

   Progress report, presented as information .... page 472

3. Substitute for wood ties.

   No report.

4. Tie renewals and cost per mile of maintained track.

   Progress report, presented as information .... page 473

5. Methods of retarding the splitting and the mechanical wear of ties, including stabilization of wood, collaborating with Committee 5, and the National Lumber Manufacturers Association.

   Oral report to be made at annual meeting.

6. Bituminous coatings of ties for protection from the elements.

   Progress report, presented as information .... page 473

7. Causes leading to the removal of ties.

   Progress in study, but no report.

8. End splitting of hardwood ties.

   Brief progress report, submitted as information .... page 475

9. Means of conserving labor and materials, including the adaptation of substitute noncritical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3-A, General Reclamation, Purchases and Stores Division, AAR.

   No report.

The Committee on Ties,
P. D. Brentlinger, *Chairman*.

AREA Bulletin 519, December 1954.

Report on Assignment 1

Revision of Manual

L. P. Drew (chairman, subcommittee), P. D. Brentlinger, W. J. Burton, E. L. Collette, R. L. Cook, H. R. Duncan, B. D. Howe, Roy Lumpkin, C. D. Turley, R. G. Wintrich.

This is a progress report, submitted as information.

Study by your committee of the material now included on pages 3–1–12, 3–1–13 and 3–1–14 of the Manual indicates that some revisions are necessary to bring it up to date.

The Specifications for Devices to Control the Splitting of Wood Ties, beginning on page 3–1–12, are limited in Art. 1. Scope, to "anti-splitting irons" only. Other devices or means of controlling splitting have been tried with some success. Your committee has assembled data based on experience by several roads, but it is felt that the information is not sufficiently conclusive to warrant a revision in the specifications at this time. It is planned to continue our studies.

On page 3–1–14, Application of Anti-splitting Devices, reference is made to hardwood ties only. On inspection trips through tie yards and of ties in test sections it has been noted that considerable splitting occurs in softwood ties as well. Tie service records of softwood ties also show a rather large percentage of ties removed because of splits.

It is, therefore, the opinion of your committee that consideration should be given to the splitting of all ties regardless of species, and it is planned to continue our studies along these lines.

Some of the devices and methods for controlling splitting being considered are:

1. Steel dowels.
2. Steel bands.
3. Incising prior to seasoning.
4. End-sealing compounds.
5. Vapor drying.
6. Seasoning under cover.
7. Kiln drying.

Report on Assignment 2

Extent of Adherence to Specifications

P. D. Brentlinger (chairman, subcommittee), C. S. Burt, G. B. Campbell, R. L. Cook, H. R. Duncan, A. K. Frost, F. J. Fudge, L. E. Gingerich, R. P. Hughes, C. E. Jackman, G. R. Janosko, L. W. Kistler, R. H. Paschal, Arthur Price, N. A. Salzano, R. G. Wintrich.

This is a progress report, presented as information.

Members of Committee 3 inspected stocks of ties at four treating plants during 1953. One trip was made in June and the other in October. The plants are located in Missouri, Texas and Illinois, and had on hand approximately one million ties in storage for six railroads. The ties were mainly oak, with some gum and other hardwoods produced in Arkansas, Illinois, Kansas, Missouri, Ohio, Oklahoma, Tennessee and Texas.

Due to curtailed procurement programs tie stocks were generally low. The quality and sizing of the ties was considered to be in accordance with AREA specifications.

Report on Assignment 4

Tie Renewals and Costs per Mile of Maintained Track

L. W. Kistler (chairman, subcommittee), J. E. Armstrong, Jr., R. W. Cook, C. M. Long, D. E. Patton.

This is a progress report, presented as information.

The annual statistics compiled by the Bureau of Railway Economics, AAR, giving information regarding the number and costs of cross ties laid in maintenance in 1953, are shown in Tables A and B in Bulletin 516, June–July 1954, following page 215. These tables will also appear following page 215 in the Proceedings, Vol. 56, 1955. According to these statistics, three regions increased and five regions decreased renewals in 1953 as compared with 1952. For the United States tie renewals decreased, the decrease being 808,864 ties, or 2.7 percent.

The average cost of ties shown in Col. 7 of Table A increased in all regions except the New England, the average of 1953 over 1952 in the United States being 11 cents, or 3.4 percent.

Although there was a decrease in tie renewals, this was more than offset by the increase in unit cost, so that the average cost of ties per mile of maintained track increased $4 in 1953, to a total of $300.

In 1953 the 5-year average number of ties renewed per mile of maintained track was 90, indicating an average service life of over 33 years. It should be of interest to know that this 5-year average per mile has decreased every year since 1946 when it was 134 ties (representing 22.4 years of life). Thus in seven years the indicated service life average has been increased 50 percent.

Report on Assignment 6

Bituminous Coating of Ties for Protection from the Elements

E. F. Snyder (chairman, subcommittee), J. E. Armstrong, Jr., L. C. Collister, B. S. Converse, R. W. Cook, B. E. Crumpler, F. J. Fudge, R. F. Garner, M. J. Hubbard, R. P. Hughes, H. W. Jensen, T. O. Manion, R. H. Paschal, C. D. Turley, G. A. Williams.

This is a progress report, submitted as information.

1952 Questionnaire

Forty-one replies were received in response to a questionnaire sent to 54 railroads on February 25, 1952, to ascertain the extent that railroads represented in the Association were using tie coatings. Answers to the questionnaire were published in Bulletin 505, December 1952 (Proceedings, Vol. 54, 1953, page 628).

The questionnaire indicates that tie coatings as a means of extending tie life are receiving favorable consideration. Material applied to the tops of ties in track as early as 1943 (Illinois Central asphalt coated track test) is still providing protection. The economic value of these applications has not been established.

Laboratory Tests

The National Lumber Manufacturers Association, in conjunction with the Association of American Railroads, has conducted a series of experimental tests to evaluate the ability of certain tie coating materials to reduce splitting and checking of ties. The latest report on these tests, dated December 4, 1953, indicates that a number of the materials have been under test for more than 50 months and are still giving serviceable protection to the tie surface. Other materials in this test show very definite weathering and thinning Tests on some of the original materials have been discontinued for one reason or another.

In reading this report and its accompanying tables it must be kept in mind that though a number of the materials have weathered to the extent of exposing a considerable area of tie surface, some of these coatings are still filling the cracks and checks in the tie surface, and to this extent are performing their primary duty, which is to keep the cracks from enlarging. However, the tie surface is no longer entirely sealed to prevent moisture loss and it is conceivable that checking and splitting will occur in these exposed areas.

Field Test on the Louisville & Nashville Railroad

Field tests conducted by the AREA and NLMA as a joint study in conjunction with studies by Committee 5—Track, of tie wear at London, Ky, on the L&N, have indicated that the coating of ties does reduce checking and splitting. These tests are in their third year and are reported in the National Lumber Manufacturers Association's report of December 4, 1953. They show that complete coverage of the top and end surfaces of ties will hold the moisture content in the top surface fairly uniform, which should prevent surface checking of the wood due to alternate drying out and re-absorbing moisture, which is the case where ties are unprotected.

Roadway and Ballast 1953 Report

AREA Committee 1—Roadway and Ballast, reported in Bulletin 514, February 1954 (Proceedings, Vol. 55, 1954, page 664), on the asphalt seal coat applied to a section of track on the Illinois Central Railroad near Manteno, Ill.

The seal coat was applied to keep dirt, cinders and moisture out of the ballast, and the sealing of splits and checks in the ties in this test section was incidental. Final inspection in 1953 showed that there has been an extension in tie life, as the renewal requirements for the test section have been half those for the adjacent track. It was also found that the heavy grade hot asphalt seems to adhere to the ties better than the cold mix materials subsequently used for patching purposes during the 10-year period of the test. The report states that additional substantiating data will be required before a general conclusion can be reached.

Track—1953 Report

AREA Committee 5—Track, reported in Bulletin 514, February 1954, on page 746 (Proceedings, Vol. 55, 1954), on a tie-coating test conducted on the Louisville & Nashville Railroad which has been in progress since July 1950. This is the same test referred to in the National Lumber Manufacturers Association report of December 4, 1953.

The subcommittee has developed a formula to determine the efficiency factor for the coating with respect to its ability to keep checks and splits covered. The test is incomplete, but it has been found that the coating is effective in retaining a high moisture content in the top of the ties.

Cost to Apply Coating Material

The cost per tie in applying various coatings on an out-of-face basis available at this time covers experimental field installations, and there is a great deal of variation in the cost of material and method of application. An out-of-face application of one or more miles of track under normal maintenance conditions will be required for a true picture of these costs.

Specifications for Coating Materials

Tentative specifications have been developed jointly by the two Associations (AAR–NLMA). These specifications cover coating materials which may be applied without heating and require materials of special properties so that they may be cut back in a solvent and flow readily at temperatures as low as 50 deg F. The specifications have been developed through laboratory tests in cooperation with the manufacturers who have submitted different materials for tests at the laboratory and in the field. These specifications need further study, and your subcommittee believes that Committee 3 must give serious consideration to the development of the specifications to include the application of heated materials and that tests should be conducted jointly with the NLMA to develop such materials.

Recommendations

1. Your subcommittee recommends that tests be continued on tie coatings under the present joint arrangement between the National Lumber Manufacturers Association and the Association of American Railroads.

2. That the tentative specifications be amended to include materials which can be applied hot to the tie surface to provide a larger field to manufacturers of tie coating products in order to develop a low price material which can be applied out-of-face in the track at relatively low cost.

3. That a questionnaire be circulated in 1955 to find what the results have been for the individual coating tests now being conducted by individual railroads.

Report on Assignment 8

End Splitting of Hardwood Ties

A. K. Frost (chairman, subcommittee), C. M. Coates, B. E. Crumpler, W. E. Fuhr, C. L. Heimbach, C. E. Jackman, G. R. Janosko, Roy Lumpkin, T. O. Manion, A. Price, M. C. Reichow, N. B. Roberts, C. V. Schutt, E. F. Snyder, S. Thorvaldson.

This is a progress report, submitted as information.

Your committee has recommended to the Board Committee on Outline of Work that the title of Assignment 8 be changed from "End Splitting of Hardwood Ties" to "End Splitting of Cross and Switch Ties", and that the study of this assignment give consideration to all classes of cross ties and switch ties.

A questionnaire calling for information concerning experience with, and treatment of, end splitting of cross ties and switch ties was mailed to the railroads represented on Committee 3. Replies have been received, are now being summarized, and a further report will be forthcoming.

Report of Committee 29—Waterproofing

T. M. von Sprecken, *Chairman,*
A. L. Becker
S. P. Berg
D. E. Bray
Lyle Bristow
R. J. Brueske
M. W. Bruns
W. H. Bunge
A. E. Cawood
R. A. M. Deal
L. P. Drew
O. E. Fort
E. T. Franzen
Nelson Handsaker
W. G. Harding
W. H. Hoar
E. A. Johnson
J. A. Lahmer (E)
J. F. Marsh
R. L. Mays
B. J. Ornburn
Henry Seitz, *Vice Chairman,*
H. A. Pasman
Milton Pikarsky
R. D. Powrie
W. E. Robey
F. S. Schubert
R. I. Simkins
J. P. Walton
C. A. Whipple (E)
K. B. Woods

Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

3. Waterproofing coatings to prevent concrete deterioration, collaborating with Committees 6 and 8.

   No report.

4. Means of conserving labor and materials, including the adaptation of substitute noncritical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3-A, General Reclamation, Purchases and Stores Division, AAR.

   No report.

The Committee on Waterproofing,
T. M. von Sprecken, *Chairman.*

AREA Bulletin 519, December 1954.

Report on Assignment 1

Revision of Manual

Henry Seitz (chairman, subcommittee), R. J. Brueske, M. W. Bruns, R. A. M. Deal, E. T. Franzen, R. L. Mays, H. A. Pasman, R. D. Powrie, F. S. Schubert, J. P. Walton.

Your committee offers the following recommendations with respect to the Manual:

Pages 29–4–1 to 29–4–5, incl.

SPECIFICATIONS FOR WATERPROOFING COATINGS FOR EXPOSED CONCRETE SURFACES

Reapprove with the following changes:

Page 29–4–2. Delete Art. 4, Sec. C and substitute the following:

4. Fabricating

The fresh concrete shall be thoroughly mixed either mechanically or by hand, carefully placed and rodded in molds forming test specimens measuring 1 in by 3 in by 8 in. The specimens shall be cast with the 3-in dimension as the vertical dimension. The molds shall be covered with damp cloths for 24 hr, after which time the specimens shall be removed from the mold and then be cured in fresh water at room temperature for 7 days. The specimens shall then be removed, all surface moisture blotted or wiped off, and weighed (W_1). At this weighing the specimen is assumed to be holding all the moisture that it can hold under these test conditions.

Page 29–4–4. Delete Art. 2, Sec. E and substitute the following:

2. Requirements for Acceptance

The acceptance of a waterproofing coating shall be determined by the ability of the coating to prevent the absorption of water by the test specimens.

The capacity of the specimen for the absorption of water before the immersion test shall be measured by the difference in weight W_1 of the specimen (Sec. C, Art. 4) and the weight W_2 when prepared for coating (Sec. D, Art. 1). This difference in weight to be expressed as D; that is, $D = W_1 - W_2$.

The capacity of the specimen for the further absorption of water after the immersion test shall be measured by the difference in weight W_1 of the specimen (Sec. C, Art. 4) and the weight W_4 of the specimen after the immersion test (Sec. E, Art. 1) less the weight W_6 of the coatings (Sec. D, Art. 5). This difference in weight to be expressed as d; that is, $d = W_1 - (W_4 - W_6)$.

Report on Assignment 2

Waterproofing Materials and Their Application to Railway Structures

Collaborating with Committees 6, 8 and 15

Nelson Handsaker (chairman, subcommittee), A. L. Becker, D. E. Bray, W. H. Bunge, A. E. Cawood, E. T. Franzen, E. A. Johnson, J. F. Marsh, B. J. Ornburn, Milton Pikarsky.

Your committee presents the following progress report, which is submitted as information. The report is descriptive in nature and is intended to familiarize the reader with the progress made to date on the investigations of bituminous waterproofing coatings and of waterproofing membranes. Final data have been taken for some tests of the former but these will be deferred until a final report is made.

WATERPROOFING BITUMENS

The investigation of waterproofing bitumens was initiated by your committee to learn more about their properties with a view toward revising our specifications where necessary to bring them up to date. Some changes have been made which were approved by the Association in 1953 and now appear in the new Manual. The most important of these were the changes in the specifications for asphalt for saturant and mopping above ground, which were made so that more manufacturers would be able to supply such an asphalt. Such changes as were made may or may not be permanent, depending on the results of the current investigation.

The work is being conducted at Purdue University by J. B. Blackburn under the general supervision of the AAR research staff at the request of your committee.

Types of Bitumens Under Investigation

Specific requirements are included in the specifications for above and below-ground asphalts, as well as requirements for emulsions that are in question, so each of these types is being studied. In addition, coal tar pitches are included to obtain a complete picture of the specification materials. Some 30 proprietary coatings were added to obtain information on new products and products not covered by our present specifications. The above and below-ground asphalts are to be compared with comparable grades of ASTM asphalts and clay-type emulsions with soap- or chemical-type emulsions.

The Testing Program

The data from three different tests have been obtained to date. These tests were (1) an immersion test for a period of a year; (2) an outdoor weathering test on the above-ground materials; (3) a laboratory weathering test on the above-ground materials involving a carbon-arc weathering machine.

The Long-Time Immersion Test

The immersion test has been by far the most time consuming and difficult to carry out. Methods of application of the coatings, handling the specimens, and weighing, all had to be devised and altered until satisfactory. The test consists of applying a coating on a concrete specimen measuring 3-in diameter by 6-in high, with a suspension wire embedded in the top of the specimen. The specimens were suspended in water and weighed at 30-day intervals for a year. The coating thickness varied between approximately 0.055 and 0.075 in.

Briefly, the results show that there is no significant difference between the efficiencies of comparable grades of AREA and ASTM asphalts for above and below-ground use. The efficiencies of these grades compared favorably with the efficiencies of tars and of asbestos-filled asphaltic cutbacks, while the efficiencies of filled asphaltic or tar emulsions varied from good to very poor. Unfilled cutbacks and emulsions were uniformly very poor, indicating that they should not be used where it is important that water should not pass through the coating.

The Outdoor Weathering Test

All of the coatings that are suitable for above-ground use were subjected to the outdoor weathering test. This test consisted of applying the coatings approximately 0.025 in thick on 1 face of slab-like concrete specimens measuring 1 by 3 by 8 in. These specimens were placed on a rack having a southerly exposure and a slope of 1 to 1.

After weathering from Sept. 28, 1953, to Sept. 28, 1954, the following observations were made. One year of weathering is not adequate really to evaluate the weathering properties of the various bitumens, and there does not appear to be any visible difference between the above-ground AREA and ASTM asphalts. Neither shows any signs of deterioration to date.

The above-ground coal tar pitches flowed off the specimens until they were no more than about 0.005-in thick. The coating that remains shows a typical weathering pattern for tar, but no deterioration is visible.

One specially processed asphaltic cement, similar to AREA above-ground asphalts, was so soft that flow wrinkles formed in the surface of the coating, but again no deterioration occurred.

It was realized at the outset that such a test as this would be of a long-time nature, but knowing how the various bitumens weather naturally will be valuable in helping to devise an accelerated laboratory weathering test.

The Carbon-Arc Weathering Test

This is an accelerated laboratory weathering test utilizing an electric arc as a source of light rays of approximately the same wave length as the light rays from a noon-day sun along the Florida coast, but of greater intensity. The specimens for this test were similar to those used in the outdoor weathering test. They were placed in the rack with a slope of approximately 1 to 1½.

The carbon arc generated a considerable amount of heat, so the temperature of the coated surfaces was in the range of 160 to 180 deg F. This high temperature caused the AREA above-ground asphalts, the coal tar pitches, and the soap-type emulsions to flow off the coated surfaces and thus very little was learned of their resistance to this type of weathering.

The ASTM above-ground asphalts did not flow from the surface, and small cracks began to appear after approximately 350 hr of exposure. The products least affected by the test were asbestos fiber filled asphaltic cutbacks, asphaltic and coal tar emulsions containing asbestos fibers, and the clay-type asphaltic and coal tar emulsions. None of the coatings of these types showed any visible weathering after 1000 hr of exposure. It is expected that these observations and future observations from the outdoor weathering test will provide the basis of modifying the carbon-arc weathering machine. This is necessary if the carbon-arc weathering is to resemble the weathering obtained from the more time consuming outdoor weathering test.

Future Investigation

Several additional tests are in the exploratory and development stage at present. Possibly the most important of these is an investigation of the temperature susceptibility of the several types of waterproofing bitumens. Such a study will involve testing the bitumens at various temperatures and in different ways to establish their behavior when subjected to changes in temperature.

Wherever practicable, future investigation of the bitumens will be correlated with the work on membrane waterproofing currently under way at the AAR Research Laboratory so that the two investigations will complement each other. It is anticipated that there will be a need for some investigative work on bitumens as a result of the tests on prepared membranes.

Conclusions

Some basic information has been obtained about the types of bitumens that were chosen for this study which will serve as a guide for future work. In general it appears that there is no difference in the waterproofing abilities of the AREA and ASTM above-ground asphalts. However, the ASTM asphalts are less susceptible to flow, and as yet there is no indication that such asphalts are any less durable than the softer AREA asphalts. Of the emulsions, the clay type is indicated as being less susceptible to flow than the soap type, but again there was no other evidence of superiority. Neither type of emulsion was effective as a waterproofing coating, but this was expected. The best all-round performance to date has been obtained with asbestos fiber filled asphaltic cutbacks. These coatings were equally as effective as the AREA and ASTM above-ground asphalts and showed excellent durability in the weathering tests. The filled asphaltic and tar emulsions were equally as durable but show erratic results in the long-time immersion test.

The course of future testing will be guided by the results to date and will be closely correlated with the membrane testing. Your committee feels confident that the information which is being obtained from these investigations will ultimately lead to better specifications for waterproofing bitumens, and at the same time make us all more aware of this important phase of construction.

WATERPROOFING MEMBRANE

This investigation is being conducted by the AAR research staff. The study includes two approaches. One is an examination of membranes which have been in service a number of years, and the other is laboratory tests made under controlled conditions.

In the first approach, members have been requested to report when and where membrane waterproofing, of at least a few years age, will be uncovered in the normal course of repair work or additions so that it may be examined by a member of the AAR research staff. One difficulty encountered in this approach has been to find as many exposures as desired for observation. While there has not yet been a sufficient number for examination to warrant definite conclusions, certain features are of such regular occurrence that it seems this phase of the study will be useful in establishing common faults. It now appears that most leakage is not through the membranes, but occurs at the edges. This is especially true on bridge decks where the membrane extends part way up a curb or similar surface. The bond is broken at this point, allowing the entrance of water which spreads under the membrane.

In the second approach, the laboratory testing of waterproofing membranes has been a more difficult problem than it might at first appear to be. Since there is no recognized method for testing such membranes, it has been necessary to develop apparatus and test methods. This is complicated by the number of variables that must be controlled and by the number of features it is desired to study.

An apparatus has been designed and assembled, and after a few trials modifications and additions were made. All the problems with the apparatus have not yet been satisfactorily solved, but it is believed that the equipment is approaching the final form that will be used.

The test specimen consists of two concrete cylinders placed end to end and held firmly in that position. Nuts on the end of a steel rod, passed through a pipe in the center of the cylinders, holds the assembly tightly as a unit, the waterproofing membrane to be studied being applied to the surface of the concrete cylinders. The specimen thus prepared is inserted in a cylindrical steel tank, after which the nuts on the rods are removed so the individual concrete cylinders may be pulled apart, simulating the movement of a crack or joint under the membrane.

Before pulling the specimen apart the cylindrical steel tank is filled with water. Failure is considered to have occurred when there is leakage at the opening formed by separating the two cylinders. The apparatus is designed so that there is an accurate measurement of the opening formed, and the rate of movement can be controlled; also, there is necessary control of the water pressure against the membrane and temperature control of the test specimen.

It now appears that the temperature of the bituminous membrane is a highly critical factor in its performance. There is still a question of the accuracy of results which can be obtained with the apparatus, i.e., how good would the agreement be if several tests were performed on the same material with the same conditions prevailing. When the apparatus is deemed satisfactory it will be used to perform tests on membrane to study such factors as the bituminous material used, the fabric used, the number of ply employed, the effect of varying pressure, the effect of low temperatures, and new materials recently developed and now on the market.

Report of Committee 8—Masonry

W. R. Wilson, *Chairman,*
R. S. Bennett
M. W. Bruns
J. R. Burkey
H. C. Charlton
M. Coburn (E)
T. L. Condron (E)
C. C. Cooke
G. H. Dayett
B. M. Dornblatt
D. H. Dowe
L. P. Drew
T. K. Dyer
G. F. Eberly (E)
W. J. Eney
J. A. Erskine
J. U. Estes
A. B. Fowler
C. W. Gabrio
W. J. Galloway
R. W. Gilmore
J. F. Halpin
J. S. Hancock
R. Hayes
D. E. Hoeffel
W. B. Jackson
A. C. Johnson
E. W. Kieckers
A. P. Kouba
J. A. Lahmer (E)
A. N. Laird
J. F. Leppman
J. C. Lerret
W. C. Love
R. L. Mays
W. L. McDaniel
E. A. McLeod
R. N. Meyer
L. M. Morris
L. H. Needham
J. R. Nutter
R. Owen
D. B. Packard, Jr.
G. H. Paris
M. S. Norris, *Vice Chairman,*
D. Patterson
R. E. Paulson
R. B. Peck
J. E. Peterson
C. B. Porter
H. Posner
C. H. Splitstone (E)
W. T. Richards
L. J. Riekenberg
J. L. Rippey
J. H. Sawyer, Jr.
C. P. Schantz
J. H. Shieber
D. H. Shoemaker
F. R. Smith
A. Tedesco
R. A. Ullery
N. Van Eenam
K. J. Waggoner
E. P. Wright
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   No report.

2. Principles of design of masonry structures, including design of masonry culverts, collaborating with Committees 1, 5, 6, 7, 13, 15, 28, 29 and 30.
   Final report on Specifications for Reinforced Concrete Culvert Pipe, submitted for adoption .... page 485

3. Foundations for masonry structures, collaborating with Committees 1, 6, 7, 15 and 30.
   No report.

4. Earth pressure as related to masonry structures.
   Final report on Exploration of Foundation Conditions, submitted with recommended affecting the Manual .... page 485

5. Tunnel linings: Design, construction and maintenance, collaborating with Committees 1, 5, 28 and 29.
   Progress in study, but no report.

6. Use of prestressed concrete for railway structures, collaborating with Committee 6.
   Progress in study, but no report.

7. Methods for improving the quality of concrete and mortars, collaborating with Committee 6.

   Progress in study, but no report.

8. Specifications for the construction and maintenance of masonry structures.

   Recommendations with respect to concrete in sea water and concrete in alkali soils or waters, submitted for adoption .... page 486

9. Means of conserving labor and materials, including the adaptation of substitute noncritical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3–A, General Reclamation, Purchases and Stores Division, AAR.

   No report.

10. Methods of construction with precast concrete members, collaborating with Committee 6.

    No report.

THE COMMITTEE ON MASONRY,
W. R. WILSON, *Chairman.*

AREA Bulletin 519, December 1954.

MEMOIR

James Fulton Leonard

James Fulton Leonard, retired engineer bridges and buildings, Pennsylvania Railroad, died at the Union Memorial Hospital, Baltimore, Md., on March 18, 1954. Interment was in Sewickley, Pa.

Mr. Leonard was born on June 5, 1879, in Salisbury, Md., the son of Col. William J. Leonard, a Civil War veteran, and Isabella Staples (White) Leonard. He attended the old Salisbury High School, and upon graduation became associated with his cousin, Dr. E. Riall White, in the drug business under the firm name of White and Leonard. Deciding to continue his education, he withdrew from the drug firm and entered Lehigh University, from which he was graduated in 1905 with the Degree of Civil Engineer.

After graduation he entered the service of the Pennsylvania Railroad, Lines West, as a draftsman in the engineering department on July 1, 1905. He was advanced to the position of assistant engineer of bridges in 1911, which position he held, with the exception of furlough time for U. S. Military Service, until 1923, when he was promoted to the position of engineer bridges and buildings, in which capacity he served until his retirement in 1949.

Mr. Leonard married Miss Margaret Trimble of Sewickley, Pa. Mrs. Leonard died several years ago. Their daughter, Mariette, is employed at the U. S. Embassy at Rome, and Mr. Leonard lived with her for some time before his final illness. He is also survived by his son, James F. Leonard, Jr., who is in the U. S. diplomatic service at Moscow.

Mr. Leonard was a prominent member of the Protestant Episcopal Church and served as a vestryman in St. Stephen Episcopal Church in Sewickley.

He joined the AREA in 1925 and was a member of Committee 8—Masonry, from 1927 through 1949. He was vice chairman of the committee from 1932 to 1937 and served as chairman from 1938 to 1941. Under his leadership the committee progressed and presented many important reports which were valuable to the railroad industry. He also served on other committees as follows:

Committee 25—Waterways and Harbors, in 1946
Committee 26—Standardization, from 1938 to 1941
Committee 28—Clearances, from 1938 to 1941

As an engineer he enjoyed a fine reputation for his ability and broad experience and judgement, and he was prominent in many important activities and projects in his official capacity with the Pennsylvania Railroad and in collaborating with the Federal Government as a representative of the American Railway Engineering Association. He was also a Life Member of the American Society of Civil Engineers.

Mr. Leonard had a fine personality and was an outstanding member of his community, and of the railroad engineering field in this country. He had many friends and he was highly esteemed by his associates. The Committee on Masonry expresses its deep regret at his death.

Report on Assignment 2

Principles of Design of Masonry Structures, Including Design of Masonry Culverts

Collaborating with Committees 1, 5, 6, 7, 13, 15, 28, 29 and 30

R. L. Mays (chairman, subcommittee), H. C. Charlton, J. U. Estes, J. S. Hancock, A. P. Kouba, A. N. Laird, J. F. Leppman, J. R. Nutter, D. Patterson, J. H. Shieber, A. Tedesko.

Last year your committee submitted, as information, Specifications for Reinforced Concrete Pipe, which appear in the Proceedings, Vol. 55, 1954, pages 476 to 485, incl. These specifications are now offered for adoption and inclusion in the Manual at the end of Part 10 of Chapter 8, with the following changes in Sec. C, Art. 5:

Delete the first sentence and replace with the following:

"If the splices are not welded, the reinforcement shall be lapped not less than 20 diameters for deformed bars manufactured in accordance with ASTM Designation A-305, and 40 diameters for cold-drawn wire and plain bars."

Delete the figure "48" in the sixth line of the paragraph and replace with the figure "36".

Report on Assignment 4

Earth Pressure as Related to Masonry Structures

R. B. Peck (chairman, subcommittee), B. M. Dornblatt, J. A. Erskine, E. A. McLeod, H. Posner.

Committee 1, with the collaboration of Committee 8, has prepared Specifications for Test Borings, which were published in the Proceedings, Vol. 55, 1954, pages 622–628, and will be submitted for adoption this year. To avoid duplication in the Manual, your committee recommends that the Specifications for Test Borings now included in Part 3, Chapter 8, pages 8-3-1 to 8-3-7, incl., be deleted when the Association adopts the Specifications for Test Borings prepared by Committee 1.

Report on Assignment 8

Specifications for the Construction and Maintenance of Masonry Structures

R. E. Paulson (chairman, subcommittee), R. S. Bennett, T. K. Dyer, A. B. Fowler, D. E. Hoeffel, N. L. Needham, J. E. Peterson, L. J. Riekenberg.

Your committee presents the following recommendations with respect to the Manual.

Pages 8–1–1 to 8–1–26, incl.

SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE RAILROAD BRIDGES AND OTHER STRUCTURES

Delete Secs. N and O on pages 8–1–21 and 8–1–22, replacing with the following:

N. CONCRETE IN SEA WATER

1. Concrete

Concrete in, or exposed to, sea water shall be made with Type II or IIA cement. Concrete in sea water from 2 ft below low water to 2 ft above high water, or from a plane below to a plane above wave action, shall contain a minimum of 1¾ bbl (7 bags) of portland cement per cubic yard in place. Other concrete in sea water or exposed directly along the sea coast shall contain a minimum of 1½ bbl (6 bags) of portland cement per cubic yard in place. The net amount of mixing water used shall not exceed the quantities shown in Table 1, Sec. J. Porous or weak aggregates shall not be used. The concrete shall contain 3 to 6 percent entrained air. Either an air-entraining cement or an air-entraining admixture may be used to produce the air-entrained concrete.

2. Depositing in Sea Water

Sea water shall not be allowed to come in contact with the concrete until it has hardened for at least 4 days. Concrete may be deposited in sea water only when so approved by the engineer.

3. Construction Joints

Concrete shall be placed in such a manner as to minimize the number of construction joints, and all construction joints shall be made as described in Sec. I, Art. 4, and Sec. L, Art. 9.

4. Cover on Reinforcement

Reinforcing steel ties or other corrodible metal shall be placed not less than 3 in from any plane or curved surface, and at corners shall be not less than 4 in from adjacent surfaces.

5. Protecting Concrete in Sea Water

Where severe climatic conditions or severe abrasions are anticipated, the face of the concrete from 2 ft below low water to 2 ft above high water, or from a plane below to a plane above wave action, shall be protected by stone of suitable quality, dense vitrified shale brick as designated on the plans or as required by the engnieer, or in special cases the protection may be creosoted timber.

O. CONCRETE IN ALKALI SOILS OR WATERS

1. Condition of Exposure

In territory where sulfate-bearing soil or sulfate-bearing water are known to occur, concrete of one of the two following classes shall be used, depending upon the severity of conditions. Severity of conditions may be judged by the extent of deterioration which has occurred to concrete previously used in the immediate vicinity or from the sulfate concentrations found in either the soil or the water.

If existing concrete has deteriorated slowly during a period of several years, or if the concentrations of water soluble sulfates in the soil are 0.1 to 0.3 percent, or if the sulfates in the water are 150 to 3000 parts per million, the conditions are considered moderately severe.

If deterioration of existing concrete has occurred rapidly during a period of only a few years, or if the sulfates found in either the soil or the water exceed the values given above, the conditions are considered severe.

2. Concrete for Moderate Exposure

Concrete for moderately severe sulfate exposure shall be made using either a Type II, Type IIA, or a Type V portland cement with not less than 6½ bags per cu yd of concrete in place and not more than 5½ gal of water per bag of cement. The concrete shall contain 3 to 6 percent entrained air. Either an air-entraining cement or an air-entraining admixture may be used to produce the air-entrained concrete.

3. Concrete for Severe Exposure

Concrete for severe sulfate exposure shall be made using a Type V portland cement with not less than 7 bags per cu yd of concrete in place and not more than 5 gal of water per bag of cement. The concrete shall contain 3 to 6 percent entrained air. An air-entraining admixture shall be used to produce the air-entrained concrete.

Note—Type V cement is not regularly stocked by most cement mills. It can usually be obtained from mills which are manufacturing this type of cement on order for the U. S. Bureau of Reclamation. If Type V cement is not obtainable, a Type II or Type IIA cement may be selected which has the lowest calculated tricalcium aluminate content of the brands available.

4. Construction Joints

Concrete shall be placed in such a manner as to minimize the number of construction joints and all construction joints shall be made as described in Sec. I, Art. 4, and Sec. L, Art. 9.

5. Cover on Reinforcement

Reinforcing steel or other corrodible metal shall not be placed closer than 2 in from the surface of the concrete and 3 in coverage shall be used wherever feasible.

Report of Committee 17—Wood Preservation

A. J. Loom, *Chairman,*
W. P. Arnold
W. W. Barger
J. A. Barnes
A. S. Barr
R. S. Belcher (E)
P. D. Brentlinger
Walter Buehler
C. M. Burpee
C. S. Burt
G. L. Cain
G. B. Campbell
H. B. Carpenter
L. C. Collister
G. H. Dayett, Jr.
R. F. Dreitzler
H. R. Duncan
T. H. Friedlin
F. J. Fudge
W. H. Fulweiler
H. F. Gilzow
R. R. Gunderson
H. M. Harlow
W. H. Hillis, Jr.
B. D. Howe
M. S. Hudson
R. P. Hughes
H. E. Hurst
M. F. Jaeger
T. D. Kern
W. C. Reichow, *Vice Chairman,*
L. W. Kistler
J. W. McGlothlin
G. L. P. Plow
R. R. Poux
M. H. Priddy
R. B. Radkey
A. P. Richards
B. J. Richards
H. M. Shudlich
W. B. Stombock
F. H. Taylor
H. C. Todd, Jr.
C. H. Wakefield
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

10. Artificial seasoning of forest products prior to treatment.

    Progress report on investigation of controlled air seasoning and one-step seasoning and creosoting processes .... page 508

11. Means of conserving labor and materials, including the adaptation of substitute noncritical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3–A, General Reclamation, Purchases and Stores Division, AAR.

    No report.

12. Treatment of laminated timber.

    Progress in study, but no report.

    Preservatives Survey, special report on preservatives used by railroads in their treatment of forest products, by M. F. Jaeger .... page 509

Report on Assignment 1

Revision of Manual

C. S. Burt (chairman, subcommittee), W. P. Arnold, Walter Buehler, C. M. Burpee, G. B. Campbell, H. R. Duncan, A. J. Loom.

Further careful study of its chapter in the Manual has engaged the attention of your committee during the past year with the view of bringing this material completely up to date with respect to methods and practices of the industry. The items which have received special attention, and the specific changes in them now under consideration, are as follows:

Page 17–1–3

PRESERVATIVES

In the third paragraph delete the words "Zinc chloride". This is being considered because less than 5 percent of the zinc-chloride-containing preservatives being used today is straight zinc chloride.

Page 17–2–1

CREOSOTE

Make editorial changes in the wording of Note 1 to clarify the now rather complex wording, and show some of the information in the note in tabular form.

Page 17–2–2

CREOSOTE–COAL TAR SOLUTION

Make editorial changes in the wording of Note 1 for the purpose of clarification, and show some of the information in the note in tabular form.

Pages 17–3–5 to 17–3–9, incl.

METHOD OF SAMPLING CREOSOTE IN TANK CARS

Study this whole procedure to determine what revisions may be required to conform to improved practices.

Pages 17–4–1 to 17–4–18, incl.

SPECIFICATIONS FOR TREATMENT

Add to the sixth paragraph of Art. 2, Sec. A, (third paragraph on page 17–4–2), the following sentences: "Ice-coated or frozen material may be steamed prior to conditioning or treatment for a total period not to exceed 2 hr. The temperature shall not exceed 240 deg F."

On Page 17–4–5 combine paragraphs 2 and 3 of Art. 1, Sec. C, and change to read as follows: "The retention of oil-borne and water-borne preservative shall be expressed pounds of dry preservative per cubic foot. The volume and specific gravity correction tables of the AREA shall be used in calculating retention."

It is the desire of this committee to progress these important questions to a decision during the months that lie immediately ahead. Accordingly, this is a progress report and is presented as information.

Report on Assignment 2

Service Test Records of Treated Wood

R. P. Hughes (chairman, subcommittee), G. H. Dayett, Jr., W. H. Hillis, Jr., T. D. Kern, L. W. Kistler, G. L. P. Plow, R. R. Poux, R. B. Radkey, W. C. Reichow, W. B. Stombock, F. H. Taylor.

Your committee submits the following report of progress in service tests of treated wood.

The Barrett Division, Allied Chemical and Dye Corporation, in cooperation with the School of Forestry, University of Florida, and Eppinger & Russell Company, Jacksonville, Fla., report on an experimental test of the preservative value of high and low-residue creosote.

The Baltimore and Ohio Railroad reports on 1953 inspections of creosoted cross ties in a 3-deg curve at Backus, Pa., at Hills–Loveland, Ohio, and at Germantown–Barnesville, Md.

The Great Northern Railway reports on 1953 inspections of ties treated with creosote inserted in 1908, and ties treated with a 50–50 creosote–petroleum mixture, inserted in 1924.

Experimental Test of Preservative Value of High and Low-Residue Creosote Barrett Division, Allied Chemical and Dye Corporation In Cooperation With The School of Forestry, University of Florida, Gainesville, Fla. and Eppinger & Russell Company, Jacksonville, Fla.

By Walter Buehler

Technologist Wood Preservation
School of Forestry, University of Florida

Creosote Oil furnished by Barrett Division from Fairfield, Ala.
Treatment by Eppinger & Russell Company at Jacksonville, Fla.
Test location, Austin Cary Memorial Forest, Gainesville, Fla.
Installation by the School of Forestry, University of Florida

1. *Creosote Quality and Quantity*

Analysis of the creosote by Barrett Research Laboratory.
Final absorption as reported by Eppinger & Russell.

	Low Residue	*High Residue*
Sp gr 38/15.5 deg C	1.070	1.135
Insoluable in benzine, %	0.34	0.49
Coke residue, %	1.50	1.23
Tar acid, %	3.5	3.5
Tar bases, %	3.0	5.0
Water, %	Trace	Trace
Standard distillation		
To 210 deg C	1.3	None
210 to 235 deg C	16.5	1.7
235 to 270 deg C	25.0	5.2
270 to 315 deg C	13.1	11.4
315 to 355 deg C	16.8	16.4
Residue	27.0	64.8
Sp gr of fractions 38/15.5 deg C		
235 to 315 deg C	1.029	1.039
315 to 355 deg C	1.105	1.102
Float test of residue		
50 deg C		36 sec
70 deg C	45.7 sec	
Absorption in pounds per cubic foot at 100 deg C		
Low residue 8.44		
High residue 8.65		

2. *Wood*

Southern yellow pine
8 pieces, 2 in by 4 in by 12 ft 0 in
Each pieces cut into 8 pieces 18 in long and identified by a metal tag. Tags numbered from 1 to 64

3. *Treatment*

Three pieces from each long piece (total 24) were treated with low-residue creosote oil. Three pieces (total 24) were treated with high-residue creosote oil, and 2 pieces (total 16) were used for untreated controls. Treatment was by the Rueping process.

4. *Installation*

Date of installation, January 1944. Each test piece was placed 9 in. in the ground. Pieces were spaced about 3 ft apart in concentric circles around a center stake.

5. *First Inspection*

First inspection was made in July 1948 by J. Calvin Goodwin, Jr., student, and Walter Buehler, technologist in wood preservation, School of Forestry, University of Florida. All untreated controls were completely decayed and destroyed by termites. The principal destruction was by termites. The decay fungus was identified as *Trametes pini*. All treated pieces showed no evidence of either decay or termites.

6. *Second Inspection*

Second inspection was made in November 1953 by G. A. Brock, student, and Dr. J. B. Huffman, assistant professor forestry products technology, School of Forestry, University of Florida.

Post Number	Low-Residue Creosote		Post Number	High-Residue Creosote	
	*Decay	*Termites		*Decay	*Termites
6	3	1	3	1	1
7	2	2	4	1	1
8	2	2	5	1	1
14	2	1	11	1	1
15	2	1	12	1	1
16	2	2	13	1	1
22	2	2	19	1	1
23	2	1	20	1	1
24	3	2	21	1	1
30	1	3	27	1	1
31	2	1	28	1	1
32	1	3	29	1	1
38	2	1	35	1	1
39	1	2	36	1	1
40	2	1	37	1	1
46	2	1	43	1	1
47	3	1	44	1	1
48	2	1	45	1	1
54	1	2	51	1	1
55	1	2	52	1	1
56	1	2	53	1	1
62	2	1	59	1	1
63	3	2	60	1	1
64	3	2	61	1	1

Inspection Grades	% Rating Value
*Decay	
1. Sound—No evidence of decay	100
2. Soft on surface—Suspicious signs	75
3. Slight but positive decay	50
4. Deep or severe	25
5. Failure—Complete loss of strength	0
*Termites	
1. Sound—No evidence of damage	100
2. Suspicion—Not positive	75
3. Slight—Positive damage	50
4. Severe attack	25
5. Failure	0

Summary of inspection

High-residue creosote oil

All pieces were sound.

Low-residue creosote oil

Decay

6 pieces were sound.

13 pieces showed suspicious signs of decay.

5 pieces showed slight but positive decay.

Termites

11 pieces showed no signs of attack.

11 pieces showed suspicious signs of attack.

2 pieces showed positive signs of attack.

Baltimore and Ohio Tie Test at Backus, Pa.

Length of Test—43 Years

Report For 1953 Renewals. Installed—November 1910

Straight Creosote, 10 Lb per Cu Ft

Kind of Wood	*Ties Placed*	*In Test*	*Removed to Date*		*Avg. Life to Date, Years*
			Number	*Percent*	
Red oak	72	7	65	90	31.6
Black oak	260	17	243	93	32.6
Pin oak	316	17	299	95	32.7
Maple	543	143	400	74	34.4
Beech	824	98	726	89	31.6
Birch	19	4	15	79	31.4
Cherry	9	1	8	89	30.0
Gum	12	1	11	92	31.8
Chestnut	170	0	170	100	21.2
Hickory	146	9	137	94	30.0
Total	2371	297	2074	87	31.6

Note—Entire test on 3-deg curve.

Baltimore and Ohio Tie Test at Hills–Loveland, Ohio

Length Of Test—24 Years

Report For 1953 Renewals. Installed—January 1930

Straight Creosote

Kind of Wood	*Absorption Pounds*	*Ties Placed*	*In Test*	*Removed to Date*		*Avg. Life to Date —Years*
				Number	*Percent*	
Red oak	4.78	600	472	128	21.3	21.7
Red oak	6.25	600	422	178	29.7	21.3
Red oak	8.17	600	408	192	32.0	21.1
60% Creosote—40% Petroleum						
Chestnut	8.97	400	2	398	99.5	12.8
Gum	8.97	400	389	11	2.75	22.9
Hickory	8.48	400	352	48	12.0	22.4
Sap beach	8.97	200	190	10	5.0	22.8
Heart beach	10.57	200	186	14	7	22.8
White oak	5.47	600	581	19	3.2	22.9
Red oak	8.15	743	638	105	14.1	22.5
R. O. (Damaged)	8.15	457	271	186	40.7	20.4

BALTIMORE AND OHIO TIE TEST AT GERMANTOWN–BARNESVILLE, MD.

Length Of Test—25 Years

Report For 1953 Renewals. Installed—Summer of 1928

Treatment		*Ties Placed*	*In Test*	*Removed to Date*		*Avg. Life to Date—Years*	*Condition*
				Number	*Percent*		
RED OAK							
8 lb Creo.-Petroleum	50–50	300	65	235	78	19.4	Fair, split, decay and rail cut
9 lb Creo.-Petroleum	50–50	900	420	480	53	22.7	Bad splits, decay and rail cut
9 lb Creo.-Coal tar	50–50	900	399	501	56	21.7	Fair to poor—decay and rail cut
10 lb Creo.-Coal tar	60–40	900	130	770	86	20.4	Good—checked
8 lb Water gas tar	100%	900	2	898	100	17.2	
9 lb Creo.-Pet.-W.G. tar	30–30–40	900	134	766	85	18.8	Poor, splits and rail cut
8 lb Creosote	100%	900	87	813	90	20.2	Fair, splits and rail cut
8 lb Creo.-Water gas tar	50–50	900	131	769	85	20.7	Splits and decay and rail cut
9 lb Creo.-Water gas tar	40–60	900	17	883	98	20.0	
10 lb Creo.-Water gas tar	30–70	900	9	891	99	20.9	
8 lb Creo.-Pet.-W.G. tar	30–50–20	900	422	478	53	21.2	Poor, split, decay and rail cut
10 lb Creo.-Pet.-W.G. tar	40–30–30	900	40	860	96	21.1	Poor, checked and split
6 lb Creosote	100%	900	56	844	94	20.7	Good—rail cut and checked
47 lb Zinc-3.75 lb Petroleum		600	0	600	100	15.6	
32 lb Zinc-4.70 lb Petroleum		600	0	600	100	16.1	
10 lb Creo.-Coal tar	80–20	900	319	581	65	22.4	Good—Some checks and rail cut
9 lb Creo.-Coal tar	70–30	900	235	665	74	22.0	Splits, rail cut
9 lb Creo.-Petroleum	40–60	900	38	862	96	21.2	Bad splits, decay and rail cut
TOTAL		15,000	2,504	12,496	83	20.3	
WHITE OAK							
5 lb Creosote-Coal tar	50–50	300	139	161	54	21.9	Poor, much decay and split
7 lb Creosote-Coal tar	60–40	300	91	209	70	20.9	Some splits, decay
7 lb Water gas tar	100%	300	3	297	99	19.9	
7 lb Creo.-Pet.-W.G. tar	30–30–40	300	128	172	57	20.6	Poor, splits and decay
6 lb Creosote	100%	300	27	273	91	19.6	Some checked
8 lb Creosote	100%	300	59	241	80	21.0	Some decay, splits
8 lb Creo.-Water gas tar	50–50	300	59	241	80	21.0	Good
7 lb Creo.-Water gas tar	40–60	300	29	271	90	20.9	Splits and rail cut
8 lb Creo.-Water gas tar	30–70	300	47	253	84	21.6	Some rail cut and checked
5 lb Creo.-Pet.-W.G. tar	30–50–20	300	126	174	58	20.4	Poor, rail cut
7 lb Creo.-Pet.-W.G. tar	40–30–30	300	52	248	83	21.7	Good, some checked and rail cut
41 lb Zinc-2.82 lb Petroleum		300	0	300	100	19.0	
7 lb Creo.-Coal tar	80–20	300	50	250	83	21.7	Fair—rail cut and checked
8 lb Creo.-Coal tar	70–30	300	127	173	58	22.7	Good, rail cut
7 lb Creo.-Petroleum	50–50	300	34	266	89	21.5	Fair, rail cut
7 lb Creo.-Petroleum	40–60	300	29	271	90	21.4	Good
TOTAL		4,800	1,000	3,800	79	21.0	
MIXED WOODS							
9 lb Creo.-Coal tar	50–50	300	233	67	22	23.8	Fair
8 lb Creo.-Coal tar	60–40	300	227	73	24	23.7	Fair, splits
9 lb Water gas tar	100%	300	6	294	98	20.3	
10 lb Creo.-Pet.-W.G. tar	30–30–40	300	181	119	38	22.0	Badly checked—some decay
8 lb Creosote	100%	300	84	216	72	20.2	Good, some checked and rail cut
8 lb Creosote	100%	300	140	160	53	22.4	Good
8 lb Creo.-Water gas tar	50–50	294	67	227	77	21.2	Good, some decay and checked
10 lb Creo.-Water gas tar	40–60	300	73	227	76	22.0	Good, some checked and rail cut

(Table continued on next page)

BALTIMORE & OHIO TIE TEST AT GERMANTOWN–BARNESVILLE, MD. (Continued)

Treatment		*Ties Placed*	*In Test*	*Removed to Date*		*Avg. Life to Date—Years*	*Condition*
				Number	*Percent*		
10 lb Creo.-Water gas tar	30–70	300	46	254	85	21.6	Rail cut
9 lb Creo.-Pet.-W.G. tar	30–50–20	300	200	100	33	23.3	Poor, decay, checks
10 lb Creo.-Pet.-W.G. tar	40–30–30	300	58	242	81	21.8	Good, rail cut
9 lb Creo.-Coal tar	80–20	300	158	142	47	23.1	Good
8 lb Creo.-Coal tar	70–30	300	142	158	53	22.9	Good, some splits
8 lb Creo.-Petroleum	50–50	300	137	163	54	22.8	Some rail cut, good
9 lb Creo.-Petroleum	40–60	300	106	194	15	22.5	Fair, some checks
TOTAL		4,494	1,858	2,636	59	22.2	
GRAND TOTAL		24,294	5,362	18,932	78	20.8	

GREAT NORTHERN RAILWAY

2316—White Birch Test Ties—Stone Arch Bridge GN Ry Minneapolis

Creosote–Petroleum Treated—50–50 Mixture

Originally Placed 1924

Average Life Expectancy 35 Years

Year	*Number Removed Each Year*	*Accumulative Total Removed*	*Percent Removed*	*Number of Years in Service*	*Tie Year Life*	*Accumulative Tie Year Life*	*Average Life of Ties Removed, Years*
1924	0	0	0	0	0	0	0
25	0	0	0	1	0	0	1
26	0	0	0	2	0	0	2
27	0	0	0	3	0	0	3
28	0	0	0	4	0	0	4
29	0	0	0	5	0	0	5
1930	0	0	0	6	0	0	6
31	0	0	0	7	0	0	7
32	0	0	0	8	0	0	8
33	0	0	0	9	0	0	9
34	0	0	0	10	0	0	10
1935	0	0	0	11	0	0	11
36	0	0	0	12	0	0	12
37	0	0	0	13	0	0	13
38	0	0	0	14	0	0	14
39	0	0	0	15	0	0	15
1940	29	29	1.2	16	464	464	16
41	38	67	2.9	17	646	1,110	16.6
42	5	72	3.1	18	90	1,200	16.7
43	8	80	3.4	19	152	1,352	17.0
44	10	90	3.9	20	200	1,552	17.2
1945	206	296	12.8	21	4,326	5,878	19.8
46	53	349	15.0	22	1,166	7,044	20.1
47	88	437	18.9	23	2,024	9,068	20.7
48	135	572	24.7	24	3,240	12,308	21.5
49	64	636	27.5	25	1,600	13,908	21.9
1950	0	636	27.5	26	0	13,908	21.9
51	0	636	27.5	27	0	13,908	21.9
52	70	706	30.5	28	1,960	15,868	22.5
53	0	706	30.5	29	0	15,868	22.5

GREAT NORTHERN RAILWAY

9337 Creosoted White Birch Test Ties

Straight Creosote Treatment 8.2 lb per cu ft

Originally Placed 1908

10 Percent Remain in Track After 45 Years of Service

Year	*Number Removed Each Year*	*Accumulative Totals Removed*	*Percent Removed*	*Number of Years in Service*	*Tie Year Life*	*Accumulative Tie Years Life*	*Average Life of Ties Removed, Years*
1908	0	0	0	0	0	0	----------
09	0	0	0	1	0	0	----------
1910	0	0	0	2	0	0	----------
11	0	0	0	3	0	0	----------
12	10	10	0	4	40	40	4.0
13	90	100	1	5	450	490	4.9
14	115	215	2	6	690	1,180	5.5
1915	230	445	5	7	1,610	2,790	6.3
16	360	805	9	8	2,880	5,670	7.0
17	36	841	9	9	324	5,994	7.1
18	36	877	9	10	360	6,354	7.3
19	994	1,871	19	11	10,934	17,288	9.2
1920	79	1,950	21	12	948	18,236	9.4
21	39	1,989	21	13	507	18,743	9.5
22	240	2,229	24	14	3,360	22,103	9.9
23	402	2,631	28	15	6,030	28,133	10.7
24	136	2,767	28	16	2,176	30,309	10.9
1925	29	2,796	29	17	493	30,802	11.0
26	278	3,074	32	18	5,004	35,806	11.6
27	201	3,275	34	19	3,819	39,625	12.1
28	221	3,496	37	20	4,420	44,045	12.6
29	221	3,717	39	21	4,641	48,686	13.1
1930	359	4,076	43	22	7,898	56,584	13.9
31	96	4,172	44	23	2,208	58,792	14.1
32	86	4,258	45	24	2,064	60,856	14.3
33	48	4,306	45	25	1,200	62,056	14.4
34	52	4,358	46	26	1,352	63,408	14.5
1935	14	4,372	46	27	378	63,786	14.6
36	95	4,467	47	28	2,660	66,446	14.9
37	100	4,567	48	29	2,900	69,346	15.2
38	210	4,777	50	30	6,300	75,646	15.8
39	363	5,140	54	31	11,253	86,899	16.9
1940	374	5,514	59	32	11,968	98,867	17.9
41	430	5,944	64	33	14,190	113,057	19.0
42	186	6,130	66	34	6,324	119,381	19.5
43	164	6,294	67	35	5,740	125,121	20.0
44	220	6,514	70	36	7,920	133,041	20.4
1945	301	6,815	73	37	11,137	144,178	21.2
46	402	7,217	77	38	15,276	159,454	22.1
47	290	7,507	80	39	11,310	170,764	22.8
48	398	7,905	84	40	15,920	186,684	23.6
49	85	7,990	85	41	3,485	190,169	23.8
1950	59	8,049	86	42	2,478	192,647	24.0
51	291	8,340	89	43	12,513	205,160	24.6
52	27	8,367	89.6	44	1,188	206,348	24.66
53	82	8,449	90	45	3,690	210,038	24.86

Report on Assignment 3

Destruction by Marine Organisms: Methods of Prevention

A. P. Richards (chairman, subcommittee), W. P. Arnold, Walter Buehler, C. M. Burpee, G. L. Cain, R. R. Gunderson, H. M. Harlow, B. D. Howe, M. F. Jaeger, R. R. Poux, F. H. Taylor.

Your committee submits the following report as information relating to the activities of marine borers and methods of prevention.

TEST PILES

The following reports have been received from E. E. Mayo, chief engineer, Southern Pacific Company:

Report of Inspection on December 4, 1953, of Specimens Furnished by Chemical Warfare Service and Placed in San Francisco Bay at Request of Dr. H. von Schrenk

Gate 25–1–A. Installed at Biological Station, Oakland Pier, July 21, 1925. Removed 1942, replaced 1946. The untreated pieces hung at this station, 1952–53, show heavy limnoria and very light teredo attack; loss in weight 26 percent.

No. 2 (Creosote and 1 percent diphenylamine chlorarsine) Heavy localized limnoria attack.

Chemical Warfare Service Test Pieces Forwarded from Edgewood Arsenal by Lt. Col. C. E. Brigham and Hung at Oakland Pier February 24, 1932. Removed 1942, Replaced 1946

Specimen	*Treatment and Retention*	*Condition*
A-11	Creosote 21.6 lb/cu/ft	Heavy limnoria attack on one side and in heartwood on ends, very light elsewhere.
D-11	Creosote plus 2½ dinitrophenol 23.7 lb/cu/ft	Moderate limnoria attack on sides, heavy attack in heartwood on ends.
E-11	Petroleum residuum plus 2½ percent dinitrophenol 22.5 lb/cu/ft	Destroyed by limnoria and teredo attack.

Report of Inspection December 4, 1953, of Specimens Furnished Through Dr. H. von Schrenk and Col. Wm. G. Atwood and Installed in San Francisco Bay Area

Barrett Manufacturing Company material placed at Station B, Pier 7, San Francisco, January 1923. Moved to Biological Station, Oakland Pier, Southern Pacific Company, December 1925. Removed 1942, replaced 1946. Total exposure to date 26 years. (P—Pine; F—Fir)

Gate	*Specimen No.*	*Treatment*	*Condition Dec. 4, 1953*
B-4	P-1	Coke oven original oil	Heavy limnoria attack.
	P-2	Coke oven solids removed	Heavy limnoria attack.
	P-3	Coke oven acids removed	Heavy limnoria attack.
	P-4	Coke oven bases removed	Heavy limnoria attack.
B-5	P-5	Coke oven oil minus residue at 360°C.	Heavy limnoria attack.
	P-6	Coke oven oil fraction 230–270	Heavy limnoria attack.
	P-7	Coke oven oil fraction up to 230	Heavy limnoria attack.
	P-8	Coke oven oil fraction 270–360	Heavy limnoria attack.
B-6	P- 9	Vertical retort original oil	Heavy limnoria attack.
	P-10	Vertical retort minus solids	Heavy limnoria attack.
	P-11	Vertical retort minus acids	Heavy limnoria attack.
	P-12	Vertical retort minus bases	Heavy limnoria attack.
B-7	P-13	Vertical retort minus residue above 360°C.	Heavy limnoria attack.
	P-14	Vertical retort minus fraction 230–270°C.	Heavy limnoria attack.
	P-15	Vertical retort minus fraction up to 230°C.	Heavy limnoria attack.
	P-16	Vertical retort minus fraction 270–360°C.	Heavy limnoria attack.
B-8	F-1	Same as P-1	Heavy limnoria attack.
	F-2	Same as P-2	Moderate limnoria attack.
	F-3	Same as P-3	Heavy limnoria attack.
	F-4	Same as P-4	Moderate limnoria attack.
B-9	F-5	Same as P-5	Heavy limnoria attack.
	F-6	Same as P-6	Heavy limnoria attack.
	F-7	Same as P-7	Heavy limnoria attack.
	F-8	Same as P-8	Heavy limnoria attack.
B-10	F- 9	Same as P- 9	Heavy limnoria attack.
	F-10	Same as P-10	Heavy limnoria attack.
	F-11	Same as P-11	Heavy limnoria attack.
	F-12	Same as P-12	Heavy limnoria attack.
B-11	F-13	Same as P-13	Heavy limnoria attack.
	F-14	Same as P-14	Heavy limnoria attack.
	F-15	Same as P-15	Heavy limnoria attack.
	F-16	Same as P-16	Heavy limnoria attack.

The untreated specimens at this station 1952–53 show heavy limnoria and very light teredo attack; loss in weight, 26 percent.

Report of Inspection of New Test Pieces Exposed to Marine Borers at Oakland Pier

The untreated test pieces exposed 192–53 had heavy limnoria attack and very light teredo attack; loss in weight 26 percent.

A.	Hercules Powder Company products exposed 1948–53 show the following conditions:	
	Rosinamine D. Test piece No. 5	Heavy limnoria attack.
B.	Cuprolignum treated pieces exposed 1948–53 showed the following conditions:	
	Cu-3, pressure treated	Heavy localized limnoria attack.
C.	Copper Naphthenate, exposed 1948–52:	
	CuNaphth, pressure treated	Heavy localized limnoria attack.
D.	Four new pieces placed April 5, 1950:	
	Standard (of Calif.) Wood Preservative	
	No. 1— 6.0 lb retention	Destroyed by limnoria.
	No. 2—13.7 lb retention	Heavy limnoria attack one side.
	Creosote	
	No. 1—12.6 lb retention	Moderate localized limnoria attack.
	No. 2— 6.2 lb retention	Moderate localized and light general limnoria attack.
E.	Portland Gas & Coke Co. Five pieces treated with "Gasco" oils.	Placed October 1951:
	HC, Gasco Creosote 14.6 lb/cu/ft	Very light limnoria attack.
	LC, Gasco Creosote 6.6 lb/cu/ft	Very light limnoria attack.
	HD, Gasco distillate 13.0 lb/cu/ft	Very light limnoria attack.
	MD, Gasco distillate 10.3 lb/cu/ft	Very light limnoria attack.
	LD, Gasco distillate 3.9 lb/cu/ft	Light limnoria attack.

TEST BOARD STUDIES

Marine test panel studies are being continued along the New England coast by the New England Marine Piling Investigation Committee under the chairmanship of S. G. Phillips, chief engineer of the Boston & Maine Railroad.

The New York Marine Piling Investigation is also being continued under the direction of Roger Gilman, deputy director, Port of New York Authority.

Under the sponsorship of the Navy Department, Bureau of Yards and Docks, Rear Admiral J. R. Perry, chief, 200 test board locations on a world-wide basis are now being investigated.

The following is a summary of the results of test board studies to date in the continental United States:

It is common custom to refer to all boring organisms by the term "marine borers." Actually, it must be remembered that there are three general categories of these organisms—Teredinidae, pholadidae and limnoria—all differing in their requirements and degrees of destructiveness.

Study of the test board data would indicate that heavy attacks by marine borers which would cause rapid destruction to unprotected submerged timber is taking place at the following locations:

Teredinidae

Massachusetts
- Buzzards Bay
- New Bedford
- Fall River
- Woods Hole
- Cuttyhunk
- Edgartown

New York
- Fishers Island
- Atlantic Beach
- Fire Island

New Jersey
- Barengat City

North Carolina
- Ocracoke
- Morehead City
- Wrightsville Beach
- Southport
- Charleston

Rhode Island
- Newport
- Block Island

Connecticut
- New London
- Niantic

Texas
- Sabine
- Galveston
- Port Isabel

California
- Samoa
- Yerba Buena Island
- San Francisco
- Monterey
- Santa Barbara
- Port Hueneme
- Santa Monica
- San Pedro
- San Diego

Delaware
- Lewes

Virginia
- Yorktown
- Norfolk
- Portsmouth

Alaska
- Kodiak
- Ketchikan

Florida
- Mayport
- Daytona Beach
- Fort Pierce
- Key West
- St. Petersburg
- Panama City
- Pensacola

Washington
- Bellingham
- Friday Harbor
- Neah Bay
- Port Angeles
- Port Townsend
- Indian Island
- Everett
- Bremerton
- Seattle
- Tacoma
- Olympia
- Westport

Limnoria

Maine
- Portland

Massachusetts
- Salem
- Charlestown
- East Boston
- South Boston
- Hull
- Quincy
- Woods Hole

Rhode Island
- Newport
- Block Island

North Carolina
- Morehead City
- Wrightsville Beach
- Southport

California
- San Pedro

Florida
- Fort Pierce
- Key West
- St. Petersburg
- Pensacola

Washington
- Friday Harbor
- Neah Bay

Marine borer activity, while not shown to be of maximum intensity during the test board studies, could cause destruction over a period of time at the following locations:

Teredinidae

Newfoundland
- Corner Brook

Maine
- Searsport
- Rockland
- Thomaston

Maine (Contd.)
- Portland
- Scarboro
- York

Rhode Island

Tiverton
Quonset Point

Connecticut

Mystic
South Groton
Allyn's Point
Saybrook
Guilford
New Haven
Bridgeport
Norwalk

Alaska

Adak
Dutch Harbor

California

Mare Island
Benicia
South San Francisco

New Hampshire

Portsmouth

Alabama

Mobile

Massachusetts

Gloucester
Beverly
Salem
Lynn
West Lynn
South Boston
Hull
Duxbury
Chatham

New York

Pelham Bay
Jamaica Bay
Rosebank, Staten Is.
Sayville, Long Is.

Limnoria

Newfoundland

Corner Brook
Argentia

Nova Scotia

Liverpool

Maine

Souhwest Harbor
Searsport
Wiscasset
York

New Hampshire

Portsmouth

Massachusetts

Gloucester
Beverly
Lynn
Hingham
Weymouth
New Bedford
Fall River
Cuttyhunk
Edgartown

Rhode Island

Tiverton
Quonset Point

New Jersey

Bayonne

North Carolina

Ocracoke
Charleston

Florida

Mayport
Daytona Beach
Panama City

Texas

Galveston
Corpus Christi
Port Isabel

California

San Francisco
Yerba Buena Island
South San Fran.
Monterey
Santa Barbara
Port Hueneme
Santa Monica
San Diego

Alaska

Adak
Dutch Harbor
Kodiak
Ketchikan

Washington

Bellingham
Port Angeles
Port Townsend
Indian Island
Everett
Bremerton
Seattle
Tacoma
Olympia

New York

Fishers Island
Pelham Bay
Brooklyn, Ft. of 26th Ave.
Jamaica Bay
St. George, Staten Is.
Rosebank, Staten Is.

Connecticut

Mystic
New London
Niantic
New Haven

Results obtained from studies at the following locations do not indicate the probability of serious damage by marine borers, though these animals are present to some extent. These areas are actually the most critical, since conditions are apparently suitable to support a few organisms. It would definitely seem that a relatively minor shift in these conditions in a suitable direction would result in much increased activity.

TEREDINIDAE

Newfoundland
Argentia

Nova Scotia
Liverpool

Maine
Machiasport
Southwest Harbor
Bucksport
Wiscasset

Massachusetts
Charlestown
East Boston
Neponset
Quincy
Hingham
Weymouth

Rhode Island
Providence

New York
Hunt's Point
Manhattan, No. River
East River
Astoria
Brooklyn Naval Shipy.
Fulton Terminal
56th Street Yard
Army Base
Brooklyn, Ft. of 26th St.
Newark Bay
St. George, Staten Is.

California
Port Chicago

New Jersey
Weehawken
Hoboken
Jersey City
Bayonne
Perth Amboy
Leonardo Piers

Maryland
Baltimore
Annapolis
Lee Hall

North Carolina
Wilmington

Alabama
Bay Minette

Texas
Beaumont

LIMNORIA

Maine
Machiasport
Thomaston
Scarboro

Massachusetts
West Lynn
Neponset
Duxbury
Chatham
Buzzards Bay

Connecticut
Allyn's Point
Saybrook
Guilford
Bridgeport
Norwalk

New York
Hunt's Point
East River
North River
Astoria
Brooklyn Naval Shipy.
Fulton Terminal
Atlantic Terminal
56th Street Yard
Brooklyn Army Base
Jamaica Bay
Newark Bay, Staten Is.
Atlantic Beach
Fire Island
Sayville

New Jersey
Weehawken
Hoboken
Jersey City
Barnegat City

Delaware
Lewes

Virginia
Norfolk
Portsmouth

South Carolina
Charleston

Alabama
Bay Minette

Texas
Beaumont

California
Samoa
Mare Island
Benicia
Port Chicago

Report on Assignment 4

Petroleum as Carrier or Extender of Creosote or Pentachlorophenol

R. J. Richards (chairman, subcommittee), W. W. Barger, J. A. Barnes, Walter Buehler, H. B. Carpenter, L. C. Collister, R. P. Hughes, M. F. Jaeger, W. C. Reichow.

This is a progress report, presented as information.

No new developments have occurred in the creosote–petroleum field. However, the committee is studying the possibility of writing a specification or classification for a petroleum product suitable for blending with creosote to replace the present specification "Petroleum for Blending with Creosote", Manual page 17–2–3.

Report on Assignment 5

Destruction by Termites—Methods of Prevention

Collaborating with Committees 6 and 7

F. J. Fudge (chairman, subcommittee), Walter Buehler, W. H. Fulweiler, H. F. Gilzow, H. M. Harlow, B. D. Howe, M. F. Jaeger, J. W. McGlothlin, A. P. Richards, H. C. Todd, Jr.

This is a progress report, submitted as information.

At the appropriate time in 1955, your committee will request from the Association of American Railroads approval of an appropriation of funds in 1956, not to exceed $100 a year, to establish a test plot on the property of the University of Florida for materials preserved against fungus and termite attack. The test plot is expected to be in use not less than 15 years.

If this project is approved and established, progress reports on it will be made by the committee as pertinent information is developed.

Report on Assignment 6

New Impregnants and Procedures for Increasing the Life and Serviceability of Forest Products

A. P. Richards (chairman, subcommittee), W. P. Arnold, J. A. Barnes, P. D. Brentlinger, H. B. Carpenter, W. H. Fulweiler, M. S. Hudson, H. E. Hurst, R. R. Poux, R. B. Radkey, B. J. Richards, H. M. Schudlich.

Your committee submits the following progress report, which is presented as information.

There are no new preservatives or processes on which information should be presented to the Association this year.

This subcommittee was requested to study the problem of determining the kind of creosote most suitable, without heating, for spraying the tie plate area after ties in track were adzed for rail relays, and to determine if pentachlorophenol solution or other preservatives are satisfactory for this purpose.

The particular problem presented in the use of the creosotes is that of crystallization at low temperatures, interfering with spray equipment. Numerous specifications covering creosotes suitable for this purpose have been in effect for a number of years. Typical of these are the oils covered by AWPA P7–54 "Creosote for Brush or Spray Treatment", which calls for the material to be "Fluid and crystal clear at 5 deg C." Unfortunately, the range of temperatures and conditions of application encountered in the different sections of the country are such that these oils are not always entirely satisfactory. It does not appear that any one oil can be economically made which alone would be the answer to the problem under all conditions. It has been found that while the specification is met under normal conditions, these oils, when subjected to much lower temperatures, do not readily return to a completely liquid condition when the temperature is varied to a moderate degree. The following is a summary of the possibilities and of the experiences encountered in the treatment of the adzed tie plate area.

1. The use of creosote covered by AWPA P7–54 could well be used under most conditions, and also under adverse conditions, if an economical method of heating these oils just prior to application could be devised.

2. A number of railroads use creosote-coal tar solutions but seem to be faced with the same problems in low-temperature areas. A continuation of this thinking is the use of pastes consisting of coal tar pitch and P7–54 creosote, which are felt to assist in waterproofing holes and in preventing further mechanical damage.

3. It is apparent that solutions of pentachlorophenol or of copper naphthenate in various petroleum oils have been entirely satisfactory to a number of railroads, some of which use these solutions continuously, others limiting their use to the colder months. The recommended solution consists of 5 percent pentachlorophenol in kerosine, No. 2 fuel oil, or diesel fuel oil. It is understood that pentachlorophenol is obtainable in a concentrated form consisting of 40 percent penta dilutable to 5 percent. In the case of copper naphthenate the solution made up with the same solvents should contain at least 2 percent copper as metal.

This committee was asked to study the development of a standard specification for petroleum for use in connection with the preparation of pentachlorophenol solutions. Some work on this assignment has been done but no report is ready at this time.

Report on Assignment 7

Incising Forest Products

W. P. Arnold (chairman, subcommittee), Walter Buehler, B. D. Howe, R. P. Hughes, W. C. Reichow, C. H. Wakefield.

This is a progress report, presented as information.

Erie Railroad

In 1950 the Erie Railroad started an incising test, which is described in the Proceedings, Vol. 52, 1951. These ties were treated with 60/40 creosote-coal tar solution in 1951 and installed in track near Burbank, Ohio. The ties were inspected in October 1954 after two years of service. The results are presented in Table 1.

Wheeling and Lake Erie Division, Nickel Plate Railroad

This test of incised ties is reported in detail in the Proceedings, Vol. 50, 1949. The test is still in progress. The last inspection was made in September 1954, and the results after 13 years of service are summarized in Table 2.

TABLE 1—ERIE RAILROAD RESULTS OF INSPECTION—OCTOBER 1954

Rating No.*	Area of Ties Between Rails		Area of Ties Outside of Rail			
			South End		North End	
	No. Ties	Percent	No. Ties	Percent	No. Ties	Percent
Group 1—Ironed and Incised						
1	208	59	134	38	139	39
2	106	30	165	46	156	44
3	41	11	56	16	60	17
	355	100	355	100	355	100
Group 2—Incised only						
1	167	53	114	37	99	31
2	115	37	158	50	176	56
3	32	10	42	13	39	13
	314	100	314	100	314	100
Group 3—Ironed only						
1	78	22	77	22	53	15
2	214	61	208	59	225	64
3	60	17	67	19	74	21
	352	100	352	100	352	100
Group 4—Controls—Neither Ironed nor Incised						
1	87	29	55	18	60	20
2	181	60	191	64	189	63
3	32	11	54	18	51	17
	300	100	300	100	300	100

*Rating No.
1—Ties without checks or having checks not greater than ⅛ in wide.
2—Ties having checks or splits greater than ⅛ in wide but less than ⅜ in wide.
3—Ties having checks or splits ⅜ in wide or greater.

Table 2—Wheeling and Lake Erie Division, Nickel Plate Railroad Results of Inspection September 24, 1954

Species	*Actual*	*Percent*	*Group 1 (Checks ⅛" or No Checks)*			*Group 2 (Checks and/or Splits Between ⅛ and ⅜")*			*Group 3 (Checks and/or Splits ⅜" and Over)*		
			Number	*% of Species*	*% of Group*	*Number*	*% of Species*	*% of Group*	*Number*	*% of Species*	*% of Group*
					Incised						
Maple	86	55.2	28	32.6	49.0	43	50.0	63.2	15	17.4	48.4
Elm	34	21.8	4	11.7	7.0	14	41.2	20.6	16	47.1	51.6
Gum	23	14.7	17	74.0	30.0	6	26.0	8.8			
Cherry	7	4.5	6	85.7	10.5	1	14.3	1.5			
Ash	4	2.6	2	50.0	3.5	2	50.0	2.9			
Sassafras	1	0.6				1	100.0	1.5			
Hickory	1	0.6				1	100.0	1.5			
Totals	156	100.0	57		100.0	68		100.0	31		100.0
Percents			36.5			43.6			19.9		
					Unincised						
Maple	81	51.9	5	6.2	41.7	47	58.0	59.4	29	35.8	44.6
Elm	42	26.9	1	0.2	8.3	10	24.0	12.7	31	73.8	47.7
Gum	23	14.7	5	21.7	41.7	16	69.6	20.2	2	8.7	3.2
Cherry	5	3.2	1	0.2	8.3	3	60.0	3.8	1	20.0	1.5
Ash	2	1.3				1	50.0	1.3	1	50.0	1.5
Sassafras	2	1.3				1	50.0	1.3	1	50.0	1.5
Hickory	1	0.7				1	100.0	1.3			
Totals	156		12		100.0	79		100.0	65		100.0
Percents		100.0	7.7			50.6			41.7		

Report on Assignment 8

Effect on AREA Standaards and Specifications of any Changes in Manufacturing Processes and Specifications for Creosote, Petroleum and Other Products

W. W. Barger (chairman, subcommittee), Walter Buehler, C. M. Burpee, W. H. Fulweiler, M. S. Hudson, A. P. Richards, B. J. Richards.

This is a progress report, presented as information.

No new developments or changes in manufacturing processes and specifications for creosote, petroleum and other products have come to the attention of the committee during the year.

Report on Assignment 10

Artificial Seasoning of Forest Products Prior to Treatment

W. P. Arnold (chairman, subcommittee), P. D. Brentlinger, C. M. Burpee, L. C. Collister, R. F. Dreitzler, H. R. Duncan, B. D. Howe, M. S. Hudson, R. R. Poux, M. H. Priddy, R. B. Radkey.

This is a progress report, presented as information

Controlled Air Seasoning

Your committee reported on this process for seasoning wood in the 1952 Proceedings, Vol. 53. At that time, the process was restricted to seasoning southern yellow pine, particularly poles. The process is now being used commercially to dry gum cross ties and switch ties.

The sponsors of this process indicate that drying times are as follows:

Commodity	*Drying Time (Days)*	*Final Moisture Content (Percent)*
Southern pine poles and timber	8–10	40
Southern pine lumber, 3 to 5 in thick	16–18	20
Gum cross ties and switch ties	16–20	50

Timber Engineering Company One-Step Seasoning and Creosoting Process

This process is still in the research stage. Preliminary information on this process was reported in the 1952 Proceedings, Vol. 53, and in the 1953 Proceedings, Vol. 54. Additional technical information has not been released for publication.

Special Report

Preservatives Survey

By M. F. Jaeger*

This is a progress report, submitted as information, bringing up to date the survey of treating practices dated March 1948, and included in the Proceedings, Vol. 50, 1949, page 402.

Comparison of the new survey with the one published in 1949 will disclose that a number of railroads have altered the absorption and/or the percentages of components in their creosote-petroleum or creosote-coal tar mixtures for the treatment of cross ties, switch ties and bridge ties, generally by 10 percent. However, the changes are not as varied as in the two previous surveys, and indications are that they represent the weighing of economies against the life expectancies of the treated products.

* Superintendent, Port Reading Creosoting Plant, Reading Company, Port Reading, N. J.

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Final

Railroad	Cross ties Percentages Creo.	Pet.	Creo.	Tar	Switch timber Percentages Creo.	Pet.	Creo.	Tar	Absorption*	Process	Remarks	Bridge ties and lumber Percentages Creo.	Pet.	Creo.	Tar	Absorption*	Piles Percentages Creo.	Pet.	Creo.	Tar	Absorption*	Process	Remarks
Atchison Topeka & Santa Fe	50	50	—	—	50	50	—	—	12 lbs.	Full Cell-Oak Rueping-Pine & Gum	—	50 / 50	50 / 50			16 lbs. Bridge Ties 8-12 lbs. Lumber	50 / 100	50 / —			8-12 lbs Dry Land Use 16-18 lbs Marine	Full Cell / Full Cell	Lumber & Piles for dry treated with 50 creo. & 50 pet. Lumber & Piles coming in contact with salt water treated with 100% creo. …
Atlantic Coast Line	—	—	70	30	—	—	80	20	5-8 lbs.	Open Cell		—	—	80	20	18 lbs. except Ties & Guard Rails 7 lbs	100	—	—	—	16 lbs.	Open Cell-Bridge Ties & Lumber Full Cell-Piling	
Baltimore & Ohio	—	—	80	20	—	—	80	20	7 lbs.	Empty Cell	Supplemented by Boulton for green ties	100	—	—	—	10-12 lbs.	100	—	—	—	14-17 lbs.	Full Cell	
Bessemer & Lake Erie	—	—	70	30	—	—	70	30	7 lbs	Rueping		—	—	80	20	8 lbs	—	—	60	40	8 lbs Dry Land Use 12 lbs Wet	Rueping	
Boston & Maine	50	50	—	—	50	50	—	—	8 lbs	Rueping	—	50	50	—	—	8-10 lbs.	—	—	60	40	12-18 lbs	Rueping & Full Cell	Use for treatment of … pine … 1 lb … Also 8 lbs. … paste …
Canadian National	50	50	—	—	50	50	—	—	7 lbs.-Soft-woods 6 lbs.-Hard-woods	Rueping	—	100	—	—	—	10 lbs. General use 16 lbs. Coastal waters	100	—	—	—	10 lbs General use 16 lbs Coastal waters	Rueping & Full Cell	
Canadian Pacific	50	50	—	—	50	50	—	—	7 lbs	Empty Cell	—	50	50	—	—	10 lbs	50 / 100	50	—	—	8-16 lbs	Empty & Full Cell	Land & fresh water … creo-pet. Empty Cell … Salt water piles 16 lbs. creosote Full Cell
Central of Georgia	—	—	60	40	—	—	60	40	5-8 lbs	Rueping	—	100	—	60	40	7 lbs. for ties, guard rail 8-16	100	—	—	—	16 lbs	Rueping & Full Cell	Creosote & bridge timber mostly treated with 100% creo. 16 lbs. …
Central of New Jersey	40	60	—	—	40	60	—	—	5-8 lbs.	Rueping & Lowry	—	40	60	—	—	8-10 lbs	100	—	—	—	12-16 lbs	Rueping & Full Cell	[illegible]
Chesapeake & Ohio	—	—	60	40	—	—	60	40	7 lbs. Red Oak	Rueping	Absorption reducing as percentage of white oak in charge increases	100	—	—	—	8-12 lbs.	100	—	—	—	12 lbs Fresh water 20-24 lbs Marine	Rueping & Full Cell	Are trying 8 lbs for … mixed oak with 3/4 or more white oak, 12 lbs for pine … for bridge timbers … material. Are … surface area being treated.
Chicago, Burlington & Quincy	50	50	—	—	50	50	—	—	8 lbs.	Full Cell white oak other Lowry or Rueping		50	50	—	—	8-10 lbs	100	—	—	—	13-16 lbs	Rueping	
Chicago & Eastern Illinois	—	—	60	40	—	—	60	40	.88 gals. per cu ft.	Lowry	—	100	—	—	—	1.3 gals per cu ft.	100	—	—	—	1.3-1.72 gals per cu ft	Lowry	…
Chicago Great Western	—	—	70	30	—	—	70	30	8 lbs.	Rueping	—	100	—	—	—	10 lbs.	100	—	—	—	16 lbs.	Rueping	
Chicago, Milwaukee, St Paul & Pacific	50	50	—	—	50	50	—	—	8 lbs.	Rueping for oak Lowry or Rueping for Douglas Fir & Larch	—	100	—	—	—	10 lbs	100	—	—	—	12 lbs Fresh water 18 lbs marine	Rueping & Lowry Full Cell	Boulton-seasoning followed by Rueping & Lowry - for all ties & lbr. Full Cell for piles.
Chicago Rapid Transit	—	—	80	20	—	—	80	20	8 lbs.	Rueping	—	100	—	—	—	2" and under 8 lbs … to … 8 lbs … and over 10 lbs.	100	—	—	—	[illegible]	Rueping	—
Chicago & North Western	50	50	—	—	50	50	—	—	8 lbs.	Rueping		50	50	—	—	8 lbs.	100	—	—	—	12 lbs. Southern yellow pine 16 lbs. Fir	Rueping	
Chicago, Rock Island & Pacific	—	—	70	30	—	—	70	30	8 lbs.	Rueping & Lowry	White oak about 8 lbs.	—	—	70	30	12-14 lbs.	—	—	70	30	16 lbs.	Rueping	
Cleveland, Cincinnati, Chicago & St. Louis	—	—	60	40	—	—	60	40	8 lbs.	Lowry	—	100	—	—	—	10 lbs.	100	—	—	—	12 lbs.	Lowry	
Delaware & Hudson	—	—	80	20	—	—	80	20	8 lbs.	Lowry	—	100	—	—	—	10 lbs.	100	—	—	—	12 lbs. or more	Lowry-Empty Cell	—
Delaware, Lackawanna & Western	—	—	70	30	—	—	70	30	7½ lbs.-5¼ gals 8½ lbs.-2½ gals	Lowry	—	100	—	—	—	10 lbs.	100	—	—	—	18 lbs.	Lowry	—
Denver, Rio Grande, Western	50	50	—	—	50	50	—	—	7 lbs.	Rueping	—	50	50	—	—	10 lbs.	50	50	—	—	12 lbs	Rueping	
Duluth, Missabe & Iron Range	50	50	—	—	50	50	—	—	7 lbs.	Rueping	—	—	—	—	—	—	—	—	—	—	—	—	… bridge timber … piles treated
Elgin, Joliet & Eastern	100	—			100	—			8 lbs. Oak 5 lbs. average for …	Rueping	—	100	—	—	—	8 lbs. for … 12 lbs. for … Pine	100	—	—	—	14 lbs. … Pine 8 lbs. … Oak 8 lbs. White post & …	Rueping	
Erie	—	—	80	20	—	—	80	20	8-8½ lbs.	Rueping	—	100	—	—	—	10 lbs.	—	—	80	20	8-12 lbs	Rueping	Piles … Rueping …
Florida East Coast	—	—	50	50	—	—	50	50	8.8 lbs.	Rueping	—	—	—	50	50	14 lbs.	—	—	70	30	22 lbs. or refusal	Rueping & Full Cell	—
Great Northern	50	50	—	—	60	40	—	—	7 lbs. Min. Cross ties 8 lbs. Min. Switch ties	Empty Cell	—	100	—	—	—	8 lbs. Min.	100	—	—	—	12 lbs. min for Land 15 lbs. min for marine	Empty & Full Cell	—
Gulf, Mobile & Ohio	—	—	[illegible]	20	—	—	80	20	8 lbs. Pine 8 lbs. Gum & Oak	Empty & Full Cell	—	100	—	80	20	8-14 lbs.	100	—	—	—	14 lbs.	Empty & Full Cell	Pine Lbr. 8-8 lbs … 100% creo Fir Lbr. 12 lbs … Oak & Gum 8 lbs …
Illinois Central	—	—	60	40	—	—	60	40	14.3 lbs. Gum 16 lbs. Pine 17 lbs. Oak	Empty Cell	—	100	—	—	—	8 lbs. Bridge ties 12 lbs. other lumber	100	—	—	—	18 lbs.	Empty & Full Cell	—
Kansas City Southern	50	50	70	30	50	50	70	30	8 lbs. creo tar solution 12½ lbs. creo-pet	Empty & Full Cell Rueping	Oak & Pine ties trtd with creo-tar sol. Gum with creo-pet when available.	—	—	70	30	12-16 lbs.	—	—	70	30	13-24 lbs	Empty & Full Cell Rueping	Platform walkways … Fir … Pine …
Lehigh & New England	—	—	60	40	—	—	60	40	8 lbs.	Lowry	—	100	—	—	—	10 lbs. creosote 1.32 lbs. C.Z.C. 1.93 lbs. C.Z.C.	—	—	—	—	—	—	1.32 … Running boards 1.93 … Fire retardant …
Lake Superior & Ishpeming	50	50	—	—	50	50	—	—	5 lbs. Cross ties 7 lbs. Sw. ties	Lowry	—	50	50	—	—	10 lbs.	100	—	—	—	16 lbs.	Rueping - Empty Cell	—
Lehigh Valley	—	—	50	50	—	—	50	50	8 lbs.	Lowry	—	100	—	—	—	8 lbs. Oak 12 lbs. Pine	100	—	—	—	[illegible]	Lowry	—
Louisiana & Arkansas	50	50	70	30	50	50	70	30	8 lbs. creo tar solution 12½ lbs. creo-pet.	Empty & Full Cell Rueping	Oak & Pine ties trtd with creo-tar sol. Gum with creo-pet. when available	—	—	70	30	10-16 lbs.	—	—	70	30	13-24 lbs.	Empty & Full Cell Rueping	Platform walkways … Fir … Pine bridge …
Louisville & Nashville	—	—	80	20	—	—	80	20	7 lbs. approx.	Rueping	—	100	—	—	—	[illegible]	100	—	—	—	16 lbs. 20 lbs. or refusal	Full Cell	20 lbs. … refusal for salt water use.
Maine Central	50	50	—	—	50	50	—	—	8 lbs.	Rueping	—	50	50	—	—	8-10 lbs.	—	—	60	40	13-18 lbs.	Rueping & Full Cell	Use for treatment of … pine …
Minneapolis, St. Paul & Sault Ste. Marie	50	50	—	—	50	50	—	—	7 lbs.	Rueping & Lowry	—	100	—	—	—	10 lbs.	100	—	—	—	12 lbs.	Rueping & Full Cell	—
Missouri, Kansas & Texas	—	—	70	30	—	—	70	30	7 lbs. Pine & Oak 9 lbs. Gum	Empty Cell	—	100	—	—	—	10-16 lbs.	100	—	—	—	14 lbs.	Empty & Full Cell	10 lbs. all pine mat'l except … rail & sway braces … guard rail & … refusal for fir.
Missouri Pacific	—	—	70	30	—	—	70	30	3/4 gal. per cu. ft.	Rueping	—	100	—	—	—	8 lbs. Ties 16 lbs. Lumber	100	—	—	—	16 lbs.	Rueping	—
National Railways of Mexico	40	60	—	—	40	60	—	—	7 lbs.	Rueping	—	40	60	—	—	7 lbs.	40	60	—	—	8 lbs.	Rueping	—
Nashville, Chattanooga & St. Louis	—	—	80	20	—	—	80	20	7 lbs. avg Red Oak 9 lbs. avg. Gum	Empty Cell	—	100	—	—	—	14 lbs.	100	—	—	—	16 lbs.	Empty Cell	—
New York Central	—	—	60	40	—	—	60	40	8 lbs.	Lowry	—	100	—	—	—	10 lbs.	100	—	—	—	12 lbs.	Lowry	
New York, Chicago & St Louis	50	50	—	—	50	50	—	—	8 lbs.	Rueping	—	50 / 100	50	—	—	8 lbs. Bridge ties 10 lbs. Lumber	100	—	—	—	12 lbs.	Rueping	… lbs. for sizes … other lumber …
New York, New Haven & Hartford	—	—	50	50	—	—	50	50	8 lbs. Cross ties 10 lbs. Switch ties	Lowry	—	100	—	—	—	8-10 lbs.	100	—	—	—	10 lbs. to refusal	Lowry	—
New York, Ontario & Western	—	—	80	20	—	—	80	20	8 lbs.	Lowry	—	—	—	—	—	—	—	—	—	—	—	—	—
Norfolk & Western	50	50	—	—	50	50	—	—	10 lbs.	Empty Cell	—	50	50	—	—	10 lbs.	100	—	—	—	12 lbs. land use 16 lbs. marine use	Empty Cell Full Cell	—
Norfolk Southern	—	—	80	20	—	—	80	20	8 lbs.	Empty Cell	—	100	—	—	—	8 lbs. Bridge ties 16-20 lbs. Lumber as required	100	—	—	—	8-20 lbs. as required	Empty Cell	
Northern Pacific	50	50	—	—	50	50	—	—	5 lbs.	Lowry & Boulton	—	50	50	—	—	8 lbs. Bridge ties 8-12 lbs. Lumber	100 / 50	— / 50	—	—	12 lbs. Marine use 10-14 lbs. elsewhere	Lowry & Boulton	100% creo. used for marine piles
Pennsylvania	—	—	60	40	—	—	60	40	6 lbs.	Rueping	—	—	—	60	40	8 lbs. Bridge ties 10 lbs. Lumber	—	—	60	40	16 lbs. Pine 10 lbs. Fir & Oak	Rueping & Full Cell	—
Pere Marquette	—	—	60	40	—	—	60	40	7 lbs. Red Oak	Rueping	Absorption reducing as percentage of white oak in charge increases.	100	—	—	—	8-12 lbs.	100	—	—	—	16 lbs. Fresh water 20-24 lbs. Marine	Rueping & Full Cell	Absorption 8 lbs. for … mixed oak with 30% or more white oak, 16 lbs. for pine … for bridge timbers … material.
Reading	40	60	—	—	40	60	—	—	7-8 lbs.	Rueping & Lowry	—	40	60	—	—	10-14 lbs.	100	—	—	—	16-20 lbs.	Rueping & Full Cell	—
Richmond, Fredericksburg & Potomac	—	—	80	20	—	—	80	20	6 lbs.	Rueping	—	—	—	80	20	6 lbs.	—	—	80	20	8-12 lbs.	Rueping	—
Seaboard Air Line	—	—	80	20	—	—	80	20	8 lbs.	Rueping	—	100	—	—	—	12 lbs.	100	—	—	—	16 lbs. Inland 18-24 lbs. Marine	Rueping & Full Cell	Bridge ties … process
St. Louis & Southwestern	70	30	—	—	70	30	—	—	7½ lbs.	Rueping	—	100	—	—	—	8-12 lbs.	70	30	—	—	16 lbs.	Rueping	Bridge ties, guard rails & walkway boards 8 lbs. … other bridge timber … lbs.
Soo Line Railroad	60	60	—	—	60	60	—	—	7 lbs.	Lowry & Rueping	—	100	—	—	—	10 lbs.	100	—	—	—	[illegible] lbs.	Rueping & Full Cell	—
Southern	—	—	60	40	—	—	60	40	8 lbs. complete penetration of … heartwood as practicable	Rueping	—	—	—	80	20	10 lbs.	—	—	80	20	16 lbs.	Rueping	—
Southern Pacific	25 / 50	75 / 50	—	—	25 / 50	75 / 50	—	—	9.8 lbs. 8 lbs.	Rueping	—	100	—	—	—	11 lbs.	100	—	—	—	14 lbs.	Full Cell & Lowry	Bridge ties treated with … per cu. ft. Tanalith …
Southern Pacific Lines in Texas & Louisiana	50	50	—	—	50	50	—	—	6-11 lbs.	Empty Cell-Pine & Gum Full Cell-Oak	11 lbs. Pine 4.8 lbs. Gum 8 lbs. Oak	50	50	—	—	[illegible]	50	50	—	—	8, 8-16 lbs.	Empty Cell-Pine Full Cell-Fir	Bridge ties & lumber - … lbs. pine … Piles 16 lbs. pine … 4.8 lbs. Fir
Texas & Pacific	50	50	70	30	50	50	70	30	8-9.8 lbs.	Lowry & Rueping	Grades 4 & 5 Gum cross ties, all grade oak cross ties, & pine & gum sw. ties trtd. with 70-30 creo-tar 8 lbs. all grade pine cross ties & … trtd with 60-50 creo-pet 9½ lbs.	100	—	—	—	14 lbs.	100	—	—	—	18 lbs.	Rueping	… & platform decking … depot & … bridge trestle with … paste … Signal … with 1. lbs. …
Union Pacific	50	50	—	—	50	50	—	—	8 lbs.	Lowry or Bethel	—	50	50	—	—	8 lbs.	100	—	—	—	12 lbs.	Lowry & Bethel	Considering use of … Chemonite for bridge ties.
Virginian	—	—	80	20	—	—	80	20	4½-8 lbs. Oak	Empty Cell	—	100	—	—	—	8 lbs. Pine 8-8½ lbs. Oak	100	—	—	—	18 lbs.	Empty & Full Cell	… pressure … for …
Wabash	—	—	[illegible]	50	—	—	50	50	2.6 gals All ties	Rueping & Lowry	—	100	—	—	—	16 lbs.	100	—	—	—	16 lbs.	Rueping & Lowry	
Western Maryland	—	—	50	50	—	—	50	50	8 lbs. cross ties 7 lbs. sw. ties	Rueping	—	—	—	50	50	7 lbs.	—	—	—	—	—	Rueping	No piles treated

*Pounds per cu. ft. unless otherwise noted

Report of Committee 27—Maintenance of Way Work Equipment

N. W. Hutchison, *Chairman,*
R. M. Baldock
Edgar Bennett
R. E. Berggren
C. T. Blume
I. M. Boone
W. S. Brown
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G. M. Strachan
M. C. Taylor
T. H. Taylor
H. A. Thyng
S. E. Tracy
A. H. Whisler
F. E. Yockey

Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

No report.

2. Motor cars, trailer and push cars, collaborating with Signal Section, AAR, Committee 10.

3. New developments in work equipment.

4. Improvements to be made to existing work equipment.

5. Tie renewal equipment.

6. Maintenance of automotive vehicles.

7. Machinery for unloading, distributing, and dressing ballast.

8. Automotive trailers for transporting work equipment.

9. Means of conserving labor and materials, including the adaptation of substitute noncritical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3-A, General Reclamation, Purchases and Stores Division, AAR.

   No report.

10. Work equipment hydraulic systems.

    Final report, submitted as information .... page 552

THE COMMITTEE ON MAINTENANCE OF WAY WORK EQUIPMENT,
N. W. HUTCHISON, *Chairman*.

AREA Bulletin 519, December 1954.

MEMOIR

Charles Hewitt Rennie Howe

Charles Hewitt Rennie Howe, retired cost engineer of the Chesapeake and Ohio Railway, died at his home in Richmond, Va., on June 17, 1954, at the age of 78. He is survived by his wife Emma Nelson Howe; three sons, Charles H. R. Howe, Jr., George N. Howe, and Donald W. H. Howe; two daughters, Mrs. Adrian Bowler, and Mrs. Julian H. Osborne, and nine grandchildren.

Mr. Howe was a native of West Boylestown, Mass., and attended Worcester Academy, Dartmouth College, and Massachusetts Institute of Technology. He was an engineer for the Panama Canal construction project from 1909 to 1911, becoming associated with the Chesapeake and Ohio in 1925.

Mr. Howe joined the AREA in 1912, became a Life Member in 1948, and a Member Emeritus of Committee 27 in 1953. His was an active membership in the Association, he having been a member of several committees, including 11—Records and Accounts, in 1947; 16—Economics of Railway Location and Operation, from 1938 to 1948; 17—Wood Preservation, in 1918 and 1919; 21—Economics of Railway Operation, from 1930 to 1937; 22—Economics of Railway Labor, from 1929 to 1934; and 27—Maintenance of Way Work Equipment, from 1931 to 1950. He served as vice chairman of the latter committee from 1938 to 1941, and as chairman, from 1942 to 1945.

Among his business associates and in private life, Mr. Howe had a multitude of friends. Those on Committee 27, of which he was a Member Emeritus at the time of his death, have lost a highly respected and valuable advisor. They, therefore, take this opportunity to express their sincere sorrow in the passing of a great friend, which expression, they feel sure, is shared by all who knew Charlie Howe.

Report on Assignment 2

Motor Cars, Trailer, and Push Cars

Collaborating with Signal Section, AAR, Committee 10

M. E. Kerns (chairman, subcommittee), R. E. Buss, E. L. Cloutier, B. E. Hayes, R. K. Johnson, C. W. Mitchell, C. E. Morgan, V. W. Oswalt, P. G. Petri, R. J. Smith, M. M. Stansbury, S. E. Tracy.

This is a progress report, including four plans which are offered for adoption and publication in the Manual.

Chapter 27 of the Manual now contains five drawings covering motor car wheels, and axles in the $1\frac{3}{16}$-in and $1\frac{7}{16}$-in sizes, namely:

Fig. 3—AREA 16-in and 20-in bolted demountable-plate wheel using ⅛-in insulating bushing for motor cars, trailers, and push cars with $1\frac{7}{16}$-in axles.

Fig. 4—AREA 14-in bolted demountable-plate insulated wheel and bushing for motor cars, trailers, and push cars using $1\frac{3}{16}$-in axles.

Fig. 5—AREA 16-in bolted demountable-plate insulated wheel and bushing for motor cars, trailers and push cars using $1\frac{3}{16}$-in axles.

Fig. 7—AREA $1\frac{7}{16}$-in axle and ring gage for motor car, trailer and push car axles.

Fig. 8—AREA $1\frac{3}{16}$-in motor car axle and end nuts.

It is desirable that specifications for at least two additional axle sizes be adopted, namely, the 2-in size and the $1\frac{11}{16}$-in size. Your committee has completed its design of these two axle sizes and the wheels to be used with them, and the present practices of manufacturers have been followed as closely as consistent with interchangeability.

The following plans, therefore, are offered as recommended practice and are submitted for adoption and publication in the Manual at the end of Part 2, Chapter 27.

Fig. 13—AREA 16-in and 20-in bolted demountable-plate insulated wheel and bushing for motor cars, trailers and push cars using 2-in axles.

Fig. 14—AREA 2-in motor car axle and end nuts.

Fig. 15—AREA 16-in and 20-in bolted demountable-plate insulated wheel and bushing for motor cars, trailers and push cars using $1\frac{11}{16}$-in axles.

Fig. 16—AREA $1\frac{11}{16}$-in motor car axle and end nuts.

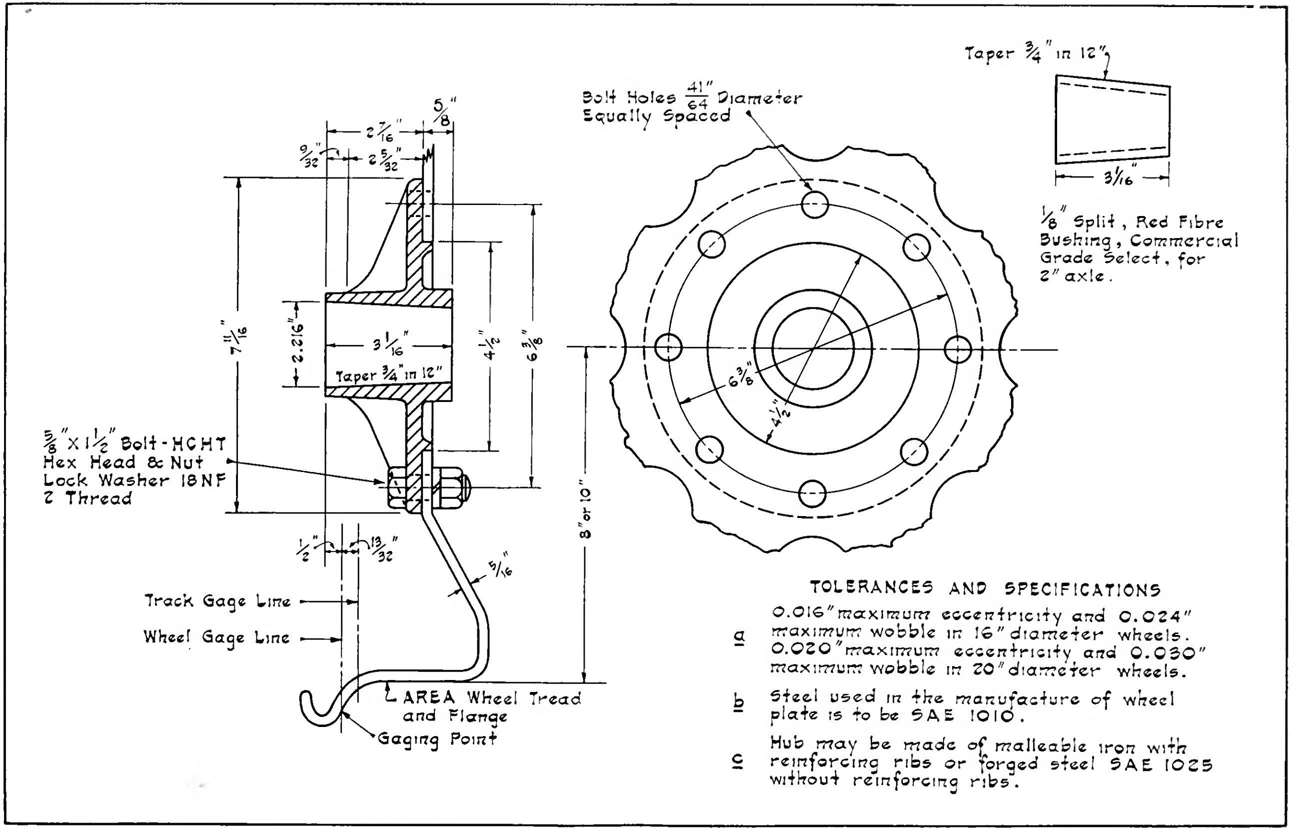


Fig. 13—AREA 16-in and 20-in bolted, demountable-plate insulated wheel and bushing for motor cars, trailers and push cars using 2-in axles.

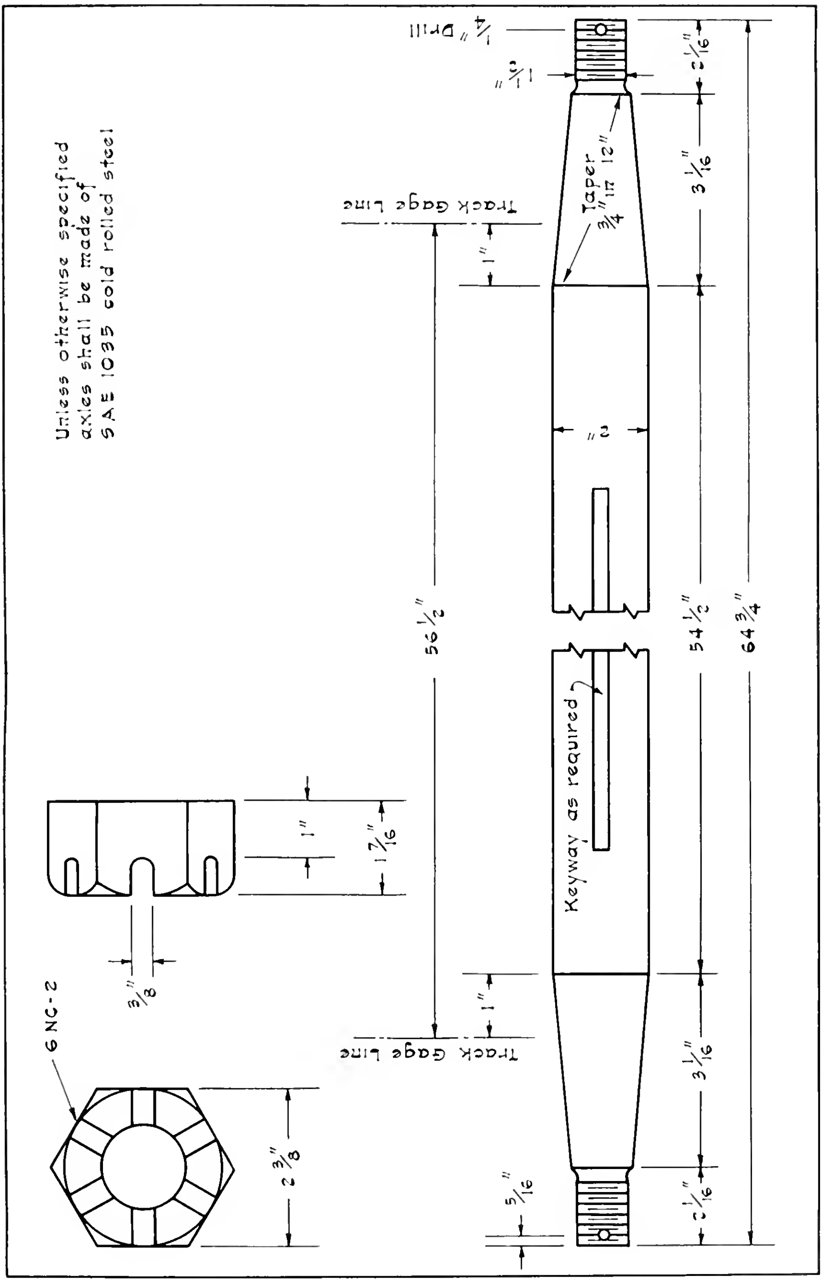


Fig. 14—AREA 2-in motor car axle and end nuts.

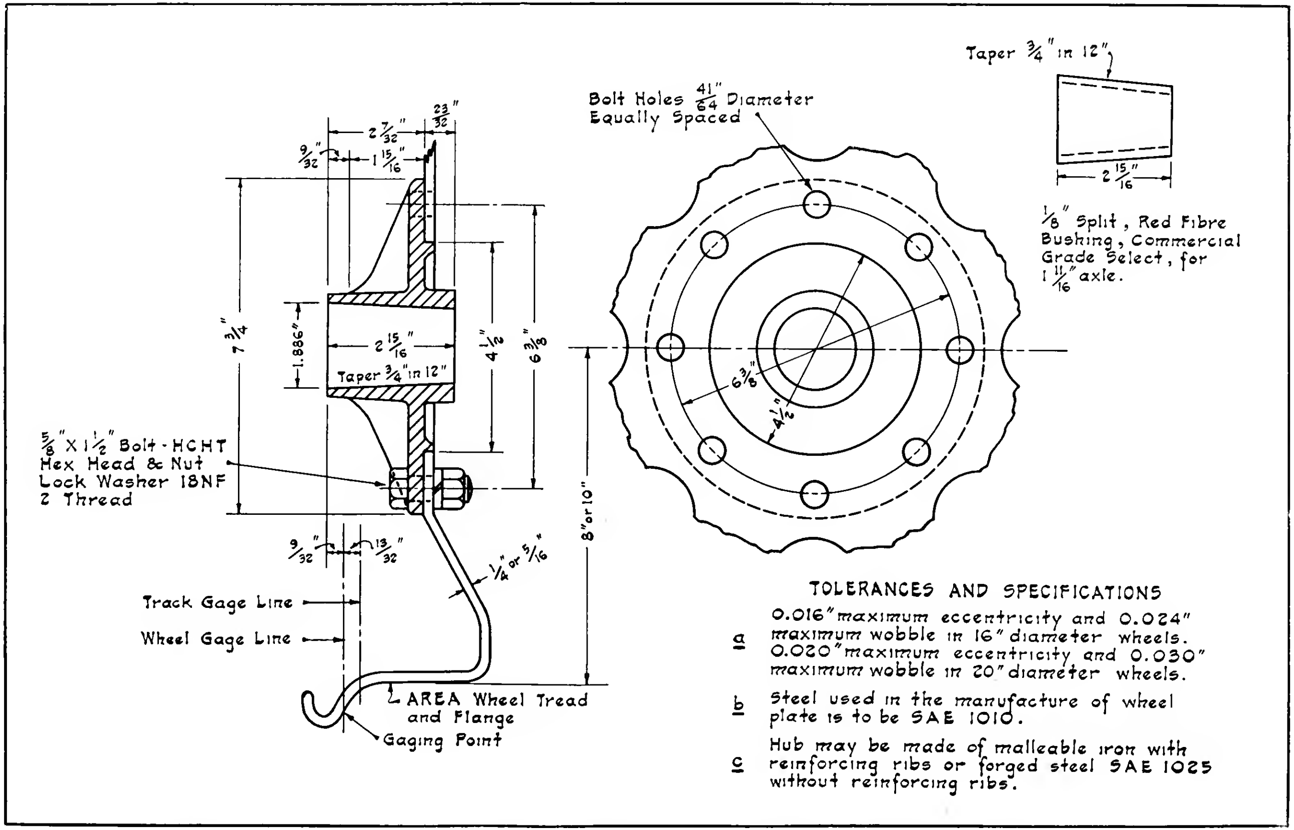


Fig. 15—AREA 16-in and 20-in bolted demountable-plate insulated wheel and bushing for motor cars, trailers and push cars using 1 11/16-in axles.

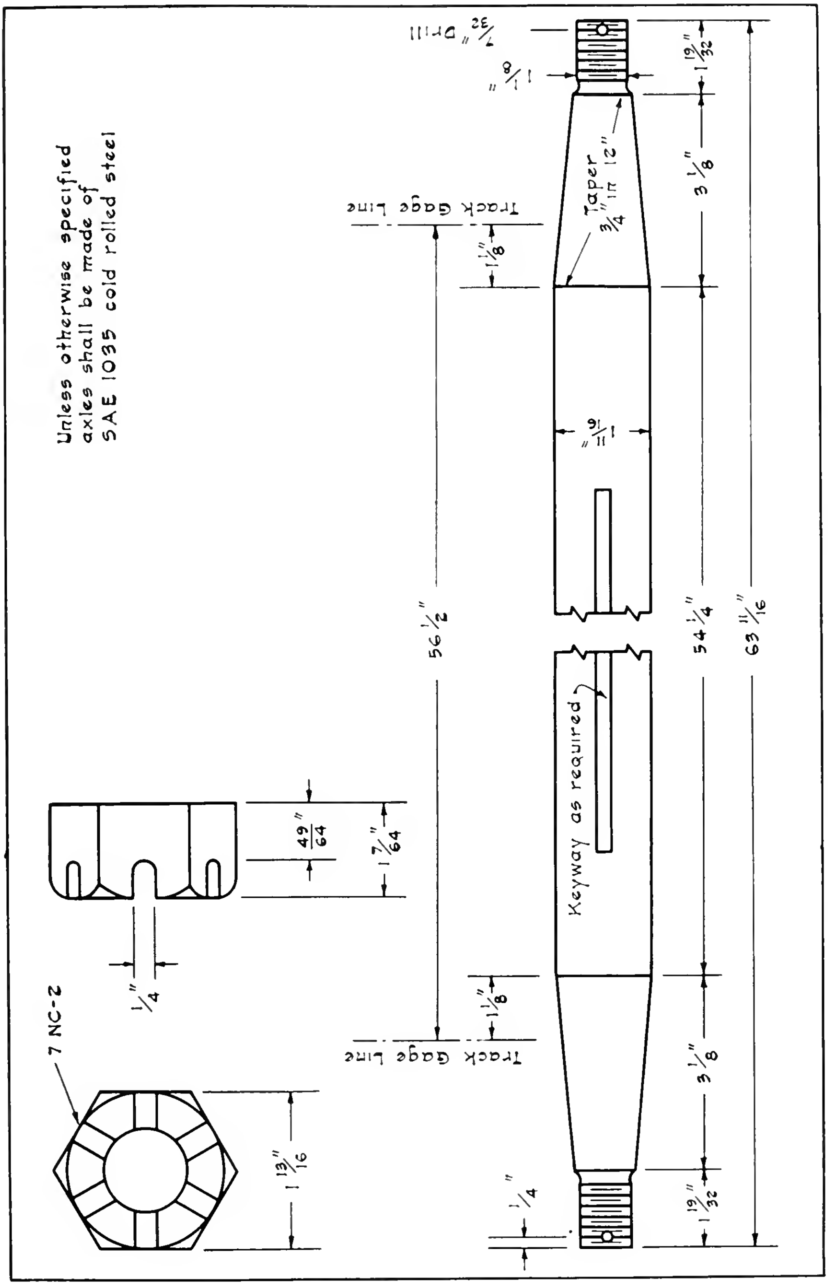


Fig. 16—AREA 1 11/16-in motor car axle and end nuts.

Report on Assignment 3

New Developments in Work Equipment

T. H. Taylor (chairman, subcommittee), R. E. Berggren, E. L. Cloutier, S. E. Haines, Francis Martin, Harry Mayer, F. H. McKenney, C. W. Mitchell, R. J. Smith, R. S. Stephens.

This is a progress report, presented as information.

Previous reports on this subject may be found in the Proceedings, Vols. 45, 50, 52, 53, 54, and 55. This current report covers new machines marketed since the last report.

Crib Reducer

A machine has been developed for use with rail gangs for digging out that part of the crib which might foul the bits of power adzers. The new machine consists of a balanced frame, mounted on double-flanged wheels, at one end of which is a digging drum, shielded for safety purposes, and at the other end a power plant.

The digging drum turns on self-alining ball bearings and has renewable teeth of abrasion-resistant alloy steel. The maximum outside diameter of the drum with teeth is 41 in. The shield for the drum is pivoted, within limits, to permit the machine to be worked at grade crossings and adjacent to platforms. Power is supplied by a single-cylinder, air-cooled engine, fitted with a power take-off, manual clutch, and hydraulic coupling. The drive includes a double V-belt to a reduction gear, and a double V-belt from the reduction gear to each side of the digging drum. An adjustable counterweight is provided to keep the machine in near balance.

The unit is propelled along the rail from crib to crib by hydraulic power, and the speed of the forward travel can be varied by a simple adjustment. Two rubber-tired set-off wheels and self-storing lift pipes aid in removing or re-railing the unit. When necessary to deadhead the machine on both rails, one of the set-off wheels is moved to the digging side of the machine and located so as to ride the rail. A lifting post also is provided for handling by a crane. The machine can be worked in either direction.

Bonding Drill

A new rail bonding drill has been made with the weight reduced to less than 200 lb by the use of aluminum alloy. It is said that the reduced weight of this model permits easy removal from the track and causes the machine to track excellently when in operation.

The unit has been designed to drill any type of rail in any worn condition. This is accomplished by easy adjustment of the drill bit to any position from 16 deg above to 16 deg below the horizontal. Adjustable elevating stops are provided to permit movement of the bit from head to web of the rail, or reverse, to an exact predetermined position.

Earth Auger

A manufacturer has announced the availability of a new earth auger. The device, powered by a 5-hp, air-cooled gasoline engine, is equipped with a one-hand finger throttle, safety stop button and automatic clutch. Available in 6, 9, and 12-in diameters, the auger can be equipped with an extension for boring holes up to 6 ft in depth. The cutting blade of the auger is of hardened steel. The pilot auger is hard-faced to withstand abrasion. Other features of the new auger include: a special drive shaft, said to eliminate side sway and vibration; gears turning in liquid grease, which are said to be 95 percent efficient; and long-wearing ball and needle shaft bearings.

Slot Grinder

A new, improved model rail-slotting grinder has been developed. The new unit has been redesigned, making it a lightweight self-contained machine of 70 lb. The design retains the wheelbarrow type of dolly for moving on the rail to the joints to be beveled or slotted, to prevent rail-end chipping.

Hydraulic Track Jack

A new hydraulic, self-propelled track jack has been announced. This is a device to speed up track jacking operations in surfacing and retimbering gangs.

The machine is hydraulically operated by one man, has a working speed up to 3 mph and a traveling speed up to 12 mph. The jack is equipped with automatic rail dogs which will operate on any section of rail, as the foot is lowered between the ties. A special turntable permits setting off the machine in approximately 1 to 1½ min. The unit is of welded steel construction throughout, has a 14-hp, air-cooled engine, a lift capacity of 12 tons, and weighs 2000 lb. It is 55 in long, 77½ in wide, and extends 60½ in above the rail. The machine is also available as a non-self-propelled unit.

Jack Carrier

A self-propelled car, designated as a jack carrier and used for transporting track jacks between the tamping machine and the advance track-raising gang, has been introduced. The use of this car entails the mounting of several small accessories on the front end of the tamping machine, including two low platforms, one at each corner, on which workmen place the jacks released as the tamping progresses.

Spike Puller

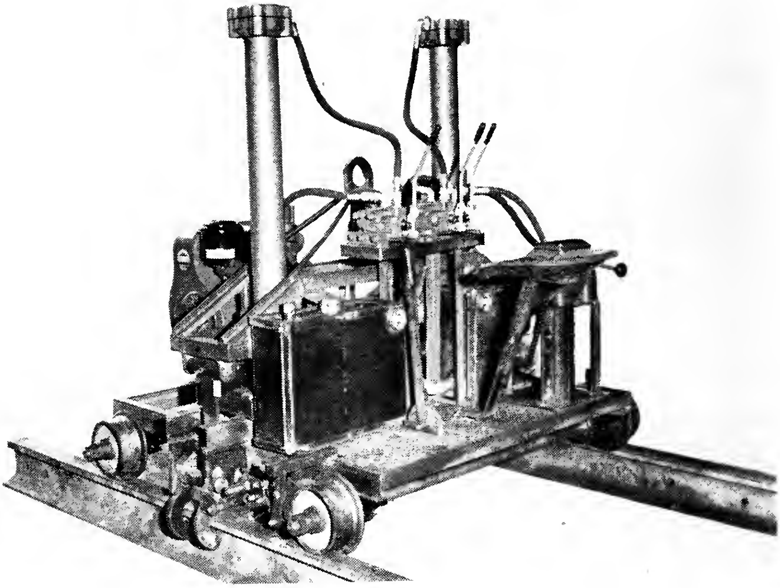
A heavy-duty, high-capacity hydraulic spike puller has been announced by a manufacturer. It is designed for rail-gang use, can be operated by one man, and is self-propelled, both forward and reverse.

The pulling assembly, controls, and operator's platform and seat are easily positioned for pulling spikes from either side of the rail, but once positioned, the pulling is done from only one side for each setting. In operation, one machine pulls the spikes from one side of the rail, and a second machine pulls those from the other side; hence the machines work in pairs.

The spike puller is powered by a two-cylinder, air-cooled engine. The hydraulic system for pulling the spikes includes a direct-driven pump, reservoir, micro filter, unloading valve, control valve, accumulator, and the pulling cylinder. The cylinder is mounted on a spring-counterbalanced pantograph frame for easy raising and lowering. The unit is propelled along the track by hydraulic power. The operator raises and lowers the pulling assembly with his left hand and controls the movement of the machine along the track with his right. A foot pedal is used to actuate the pulling cylinder control valve. The frame is fitted with a lifting post to permit handling with a crane. Set-off equipment, consisting of two rubber-tired set-off wheels and self-storing lift pipes, is also available.

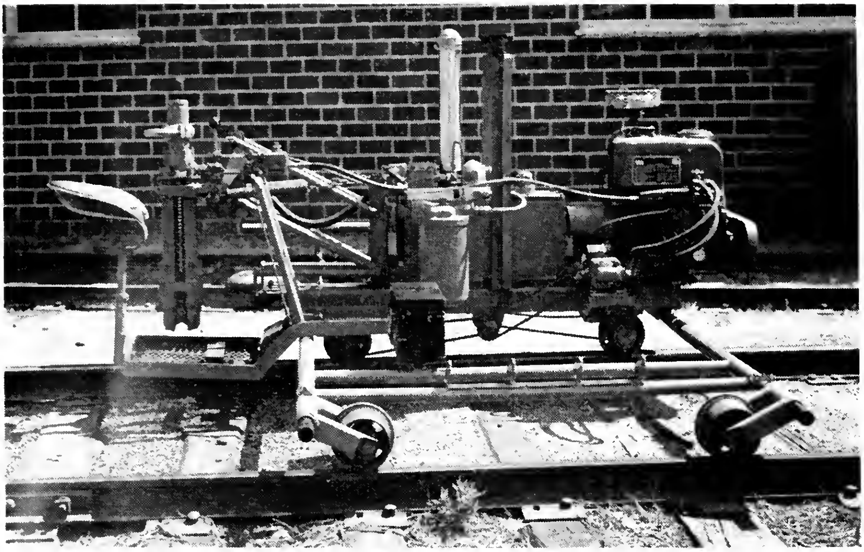
Tie Brush

A new tie brush has been announced by a manufacturer. It is designed for use by rail gangs for sweeping the ties ahead of power adzers. The wire-brush wheel turns on self-alining ball bearings, and is driven by a single-cylinder, air-cooled engine, through a reversible reduction-gear clutch and a drive shaft having heavy-duty universal joints. The brush is 20 in. in length, and 15 in. in diameter, and is shielded by a safety hood and rock guard.



Hydraulic track jack.

Jack carrier.



Spike puller.

Hydraulic power is used to propel the unit at a suitable working speed, which can be varied merely by changing the setting of a by-pass valve at the pump. Normally the brush just clears the ties, being held up by a spring in the skid that slides along the ties. In use, the operator bears down on the handle and causes the brush to contact the ties.

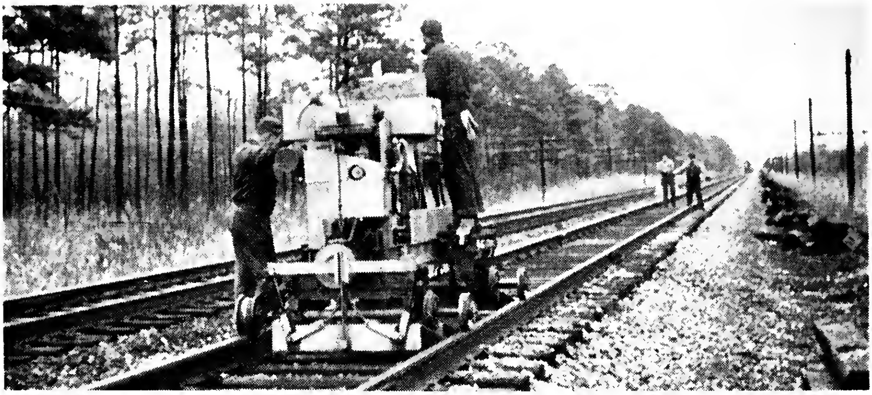
The machine can be worked in either direction because the brush drive, propelling drive, and operator's handle are all reversible. Two rubber-tired set-off wheels aid in removing the unit from the track or in re-railing it. When necessary to deadhead the machine on both rails, provision is made for applying one of the set-off wheels to the brush side where it rides on the ball of the rail.

Track Liners

The new track liner is an on-track, hydraulic machine for alining track. Power for propulsion and for its hydraulic pump is supplied by a 12-hp, 2-cylinder, air-cooled gasoline engine. The machine has forward and reverse speeds up to 20 mph.

The machine is equipped with clamps and shoes; the clamps engage the rail and the shoes lift the machine and about 90 percent of the weight of the track so that the track will move easily. The clamps are located at each end of the machine and are lowered between the rails. Projections on the ends of the clamps automatically move out to grip the undersides of the rail heads. While the operator lowers these rail clamps, the machine laborer positions two lining shoes into the cribs, which shoes are located under the center of the machine. After such positioning, the operator lowers the lining shoes. This is done through a double-acting vertical ram, which pushes cleats on the shoes into the ballast, giving a firm grip on the ballast.

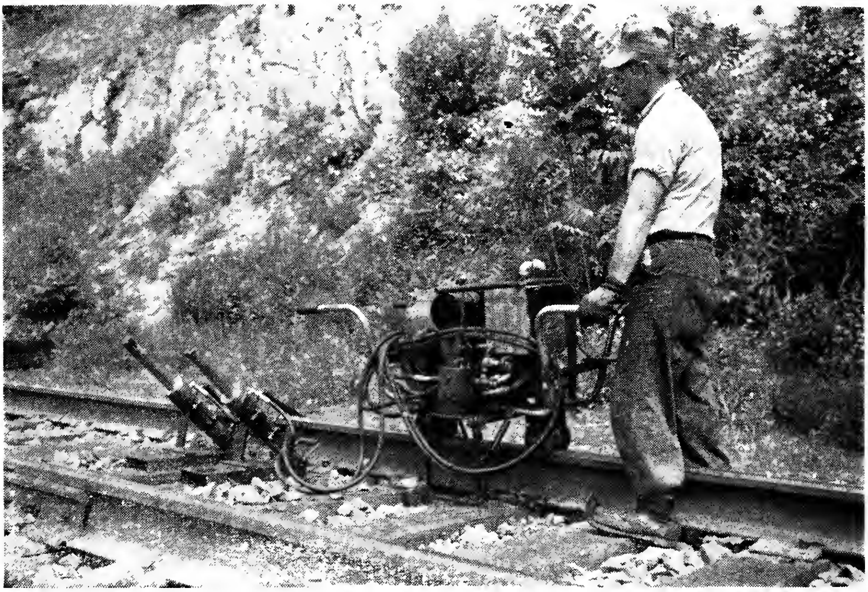
Two shoes instead of one are used to provide greater stability for the machine when exerting pressure against track in an alining operation. No pressure is exerted sideways against the wheels or wheel flanges at any time. All lateral pressure is taken up by the



Track liner.

shoe and the shoe cleats. The downward pressure on the shoes tends to raise the rails slightly by means of the clamps at each end of the machine. This makes it easier to shift the track laterally.

Actual alinement of the track is accomplished by the pressure exerted by two thrust bars, each actuated by two single-acting hydraulic rams. The thrust bars push against the rail at two separate points, with the shoes under the machine serving as the fixed base. Each ram is actuated by two opposed hydraulic cylinders, the direction and amount of the push being under the control of the operator, with a push of approximately 5000



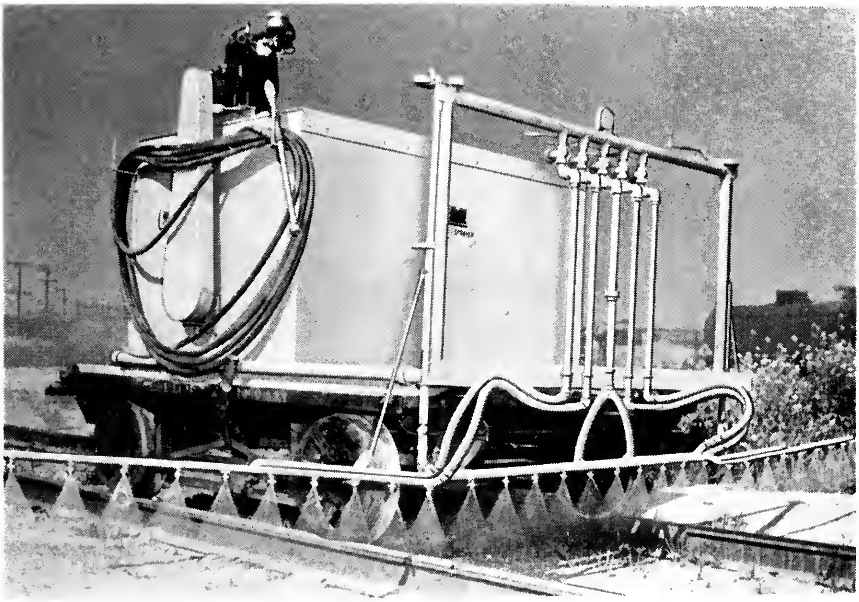
Track liner.

lb being imparted to the track by each thrust bar. Range of lateral movement extends up to 3½ in. Should additional movement of the track be needed, the shoes can be reset in the same cribs and the operation repeated, giving an additional 3½ in. Adjustment for the weight of the rail used, and the condition of the track, can be made through a pressure control in the lines to the vertical lift rams.

A second new track liner is now available, the unit consisting of two hydraulic rams, and a portable power plant. The power plant is a 6-hp air-cooled engine driving a hydraulic pump with a capacity of 3 gpm. The power plant is available as a wheebarrow-mounted off-track machine or with two-flanged wheel, dolly-mounted, for on-track operation. It is said that this unit is capable of lining turnouts, road crossings and curves, using both hydraulic rams. When lining newly raised track, one ram is sufficient.

Weed Sprayer

A weed sprayer, especially designed for treating yards, industrial spurs and off-track areas usually reached by hand-cutting methods, has been announced. The unit can be mounted on a standard motor car trailer, with no conversion or attachments necessary. The pump has a capacity of 25 gpm at 60 lb pressure. It will spray 16 ft in width while



Weed sprayer.

traveling at a speed of 6 mph. Standard equipment on the weed sprayer includes an air-cooled 5-hp engine with remote hand throttle, oil bath air cleaner, heavy-duty pump with replaceable bronze liners and impeller, stainless steel shaft, out-board ball bearings, flexible direct-drive coupling to engine, self by-passing; a 0 to 300-lb pressure gage; a welded steel tank with internal bracing; welded pipe fittings; and large manhole-type fill opening. The standard model tank holds 400 gal and an optional tank of 600 gal capacity can be furnished.

Spraying equipment includes one rigid boom with nozzles for spraying between the rails, two flexible-mounted side booms, and two 50-ft lengths of spraying hose with hand spray guns. The side booms are divided into two sections, with individual cut-off valves in each. A manually operated swivel enables the operator to swing the booms back against the car for track clearance. Adjustable linkage provides vertical positioning of the side booms as desired. Spray nozzles with interchangeable tips are furnished. A separately powered agitator, for use with weed killers requiring continuous mixing, is available as an accessory.

Safety Crank

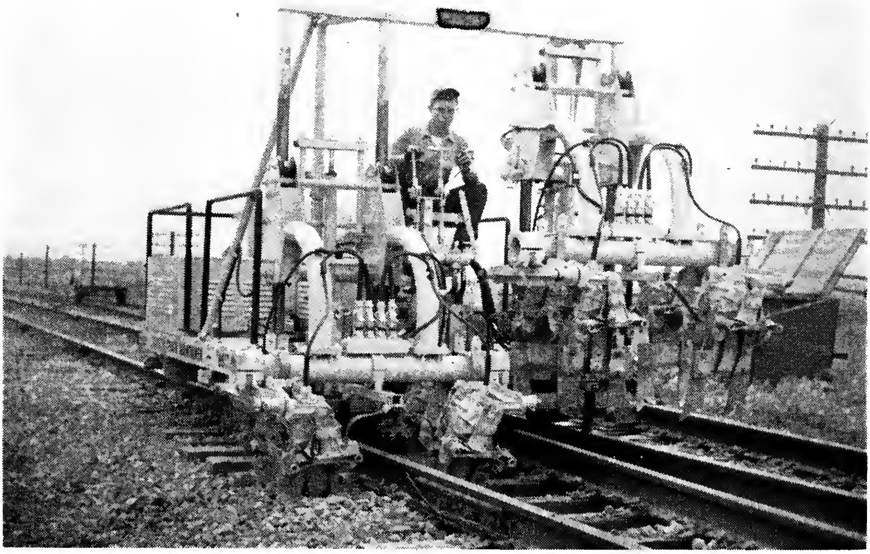
A device known as a safety crank has been introduced that is designed to eliminate accidents caused by cranking any type of internal combustion engine. It is so designed that it can be mounted on any engine that uses a crank or rope.

It is an all steel fabricated product, precision machined, to insure smooth, easy and positive operation, and is equipped with an over-running clutch that stops all counter-clockwise motion of the crank handle, thus preventing injury to the operator of the engine. It also has a friction clutch which is designed to eliminate any damage to the engine that may be caused by reverse motion, such as compression rock-back or back fire.

Vibratory Tamper

A manufacturer has announced an entirely new vibratory tamper. It is said that the effectiveness of the tamping heads has been increased about 5 times through the use of a specially designed vibratory motor which operates in a frequency range of from 4000 to 4500 vibrations per minute.

The tamping heads, each of which carries 2 hard-tipped tamping bars, available and interchangeable in 2, 3 and 5-in widths, are mounted in 2 independent groups of 4 units



Vibratory tamper.

each, 1 group to each section of the split crosshead. Each tamper and its motor is suspended from the crosshead by means of a shock-absorbent support of heavy belting.

The crossheads are each raised and lowered vertically by double-acting hydraulic rams. The down-stroke pressure is controlled by the operator, as required, to achieve full penetration of the tamping bars. It is reported that maximum pressure on the tamping heads will raise the machine from the rail. The tamping heads are adjustable for penetration as well as to height for various sections of rail, and this adjustment is controlled by the operator.

The machine is equipped with a 4-cylinder engine for chassis propulsion, has a maximum transit speed of 25 mph, a 4-wheel drive, and 3 speeds, both forward and reverse.

For operation of the generators that furnish power to the tamping heads and the main hydraulic system, a 6-cylinder engine, capable of producing 55 bhp at an operating speed of 1600 rpm, has been provided.

The tamper has an overall length of 16 ft, a maximum width of 9 ft 8 in, and an overhead height of 7 ft above the top of rail. The chassis platform is 8 by 11 ft. The machine has a total weight of 12,320 lb and is equipped with transverse set-off wheels.

Report on Assignment 4

Improvements To Be Made to Existing Work Equipment

L. E. Conner (chairman, subcommittee), R. M. Baldock, I. M. Boone, Haynie Hornbuckle, W. F. Kohl, Jack Largent, Francis Martin, E. L. Mire, V. W. Oswalt, Sr., M. C. Taylor.

This is a progress report, submitted as information. It is a continuation of previous progress reports submitted by this committee and published in the Proceedings, Vol. 53, 1952, page 396, and Vol. 54, 1953, page 666, and covers changes in work equipment that this committee has found to be both practical and desirable.

Power Rail Layer

This machine is designed for placing rail in track from the shoulder of roadbed, requiring three men to operate the older models and two men to operate the recent model.

Suggested improvements to this machine are:

1. Extend the boom 20 in so that a rail can be lifted straight up from berm of the track shoulder. The present boom is too short, and the boom chain first has to pull the rail at an angle until it comes in directly under end of boom before it actually starts to lift the rail so that it can be laid in track. This slows up operation. In extending the boom a suitable counterweight should be added to compensate for the greater boom reach. The extension should be designed with a hinge to enable the operator to fold it back to prevent fouling adjacent track.

2. Reinforce the lower cross member angles at the corners where they are bent to fit against main wheel axles. These angle bends frequently break, delaying the work.

3. Provide a pilot bearing about the center of the long drive shaft to prevent it from "whipping." Also, provide a more positive locking device to hold the thrust collars in place on the shaft to prevent it from sliding in and out when the unit is traveling.

Power Ballast Regulator

This machine is designed for spreading ballast away from the heads of the ties or to pull ballast in from the berm, shape and dress it.

Suggested improvements to this machines are:

1. Install a brush to sweep loose ballast from the tops of ties back into the cribs.
2. The ballast plow should be arranged so it can be raised and lowered mechanically. This would lessen operator fatigue and improve the efficiency of the operation.

Report on Assignment 5

Tie Renewal Equipment

L. B. Cann, Jr. (chairman, subcommittee), R. M. Baldock, I. M. Boone, W. S. Brown, F. L. Etchison, W. T. Hammond, W. E. Kropp, Harry Mayer.

This is a final report, submitted as information.

The subject "Tie Renewal Equipment" is very timely. In recent months a number of such machines and tools have been produced and are now available from many of the leading manufacturers.

The development of tie renewal equipment has advanced for two reasons. The first is economy. The cost of labor in maintenance gangs has steadily increased in recent years and is now at a point where the railroads are searching for machines and tools that will bring the installation cost per tie to the minimum. We have reports that some roads are using mechanized gangs equipped with the latest tie renewal equipment.

The second reason is the development of the mechanical tamper. This has made it necessary for maintenance-of-way managements to take a new look at their tie renewal programs. The need for more efficient methods of making tie renewals to prepare track for mechanical tamping at a rate comparable to the footage rate of today's mechanical tamper has never been greater. The desire for new equipment which can step up the tie renewal rate to meet the mechanical tamping rate has resulted in many new pieces of tie renewal equipment being placed on the market. Some of the machines that are now being used are described briefly in the following.

Tie Remover and Tie Replacer

Two companion tools facilitating the removal and insertion of ties are now being used by many railroads. Basically, each is a manually operated jack which, when attached to a rail, exert a horizontal force by means of a rack bar.

Opertion of the tie remover must be prefaced by removal of the tie plates, loosening the ballast at both ends of the tie, and removing the ballast to a level with the bottom of the tie at the pushing end. The tie remover is then attached to the rail with the pushing head of the rack bar against the tie end, and is ready for operation.

With the tie inserter, the end of the rack bar is hooked over the rail and the new tie, partly inserted under the first rail in the cavity left by the old tie, is pushed into position as the tie replacer housing travels the rack bar. These units will foul the near rail of a second track in multiple-track territory.

The end of each unit is equipped with a roller enabling it to be moved along the top of the rail. The tie remover weighs 62 lb, is 98 in long overall and has a travel of 80½ in. The tie inserter weighs 60 lb and is 116 in long overall with an 86-in travel.

Tie Pusher

This tool is designed to remove old or defective ties from the track by either section gangs or large extra forces. After the tie to be removed has been selected, the spikes in adjacent ties are loosened and all spikes and tie plates removed from the tie to be taken out. The tie pusher is then placed against the rail where the tie plate has been removed and the tie removal operation begins. The lever of the tie pusher should be at an angle of approximately 30 to 50 deg to obtain the most leverage to start the tie moving. After the tie is started the full leverage can be used in the extraction of the tie.

After the tie has been removed it is necessary to clean out the crib and install a new tie in the normal manner.

The tie pusher has 2 set screws on the head which can be set to fit all sizes of rail. It is of welded steel construction and weighs 47 lb.

Tie Puller and Inserter

A new machine designed for use in out-of-face tie renewal and track-raising work is a combination tie remover, inserter, and light crane. Essentially, the machine is a 4-wheeled frame with a power winch and telescoping boom. To use the machine as a tie puller, the boom is lowered to a nearly horizontal position at right angles to the track, with a brake and thrust member in contact with the gage side of the rail on the operator's side of the track. The winch cable is secured to the tie by tongs, force is applied, and the tie is removed.

To insert ties, the boom is rigged at a 45-deg angle with a demountable thrust member placed on the machine and against the rail under which the tie must first pass. The cable is then passed around the sheave and out over the head of the rail. The free end of the cable has tongs which grip the tie to be replaced. One man operates the winch

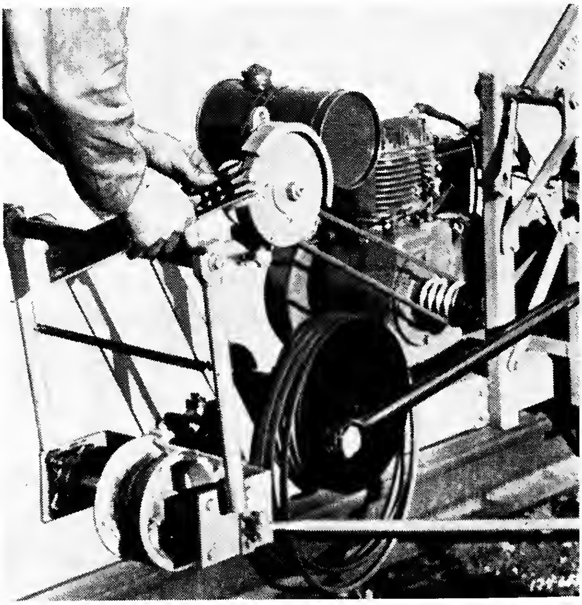
Tie puller and inserter.

while a second man guides the tie being inserted by means of a long handle equipped with a special set of tongs.

Employed as a crane, the machine will lift loads up to 2000 lb and is useful in handling light track machinery. The unit's power is derived from an air-cooled, single-cylinder, 5-hp gasoline engine. It is self propelled in either direction at speeds up to 12 mph. The frame carries a 17-ft telescoping boom which is raised or lowered mechanically and swung manually in a 180-deg arc.

Tie Cutter

The purpose of this machine is to saw, in track, the ties to be removed either by hand or by a tie-end remover. First it is necessary to remove the ballast from the sides of the ties at the points to be cut in order that saw blades will not be damaged by the ballast. After the ballast has been removed the saw cuts through the tie adjacent to the tie plates inside of each rail. This is done by a reciprocating saw blade driven by a multiple V-belt drive powered from a single-cylinder, 4-cycle engine.



Tie cutter.

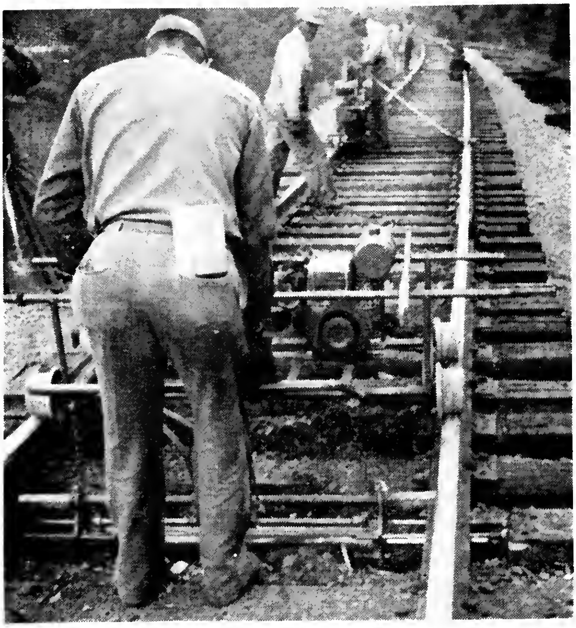
The undercarriage of this tie cutter permits cutting a tie without lifting or turning the machine around. After a tie has been cut on one side the cutting unit is rolled across the undercarriage and the same tie is cut on the other side.

With a net weight of 280 lb, the tie cutter can be lifted off the undercarriage, which weighs 128 lb, when removing the machine from the track. This makes manual removal easier.

Each machine is equipped with a ball-bearing grinder for resharpening saw blades. The blades are attached to the saw arm and may be removed easily. A number of optional but desirable accessories are available for use with this machine.

Tie-End Remover

The tie-end remover is used in a tie renewal operation immediately behind a tie cutter as a companion machine. After a tie has been cut on the gage side of both tie plates the tie becomes divided into three components. The center section is lifted out by hand with the aid of tie tongs. The tie-end remover with its double-ended hydraulic cylinder is then lowered into the tie bed. The two pistons move oppositely outward as



Tie end remover.

the control valve is opened, pushing both tie ends clear of the rail. This operation is designed to remove either a single or double-shoulder tie plate along with the portion of the tie, regardless of section of rail or density of ballast.

The hydraulic system for this machine is developed from a 6-hp, air-cooled engine. Its entire weight is 360 lb.

Tie Replacer

A hydraulic tie puller and inserter and a hydraulic jack have been combined into one unit by one equipment manufacturer. This machine is used principally in tie renewal gangs or surfacing gangs. The tie renewal gang uses it to remove the old tie from its position under the rails and to insert the new tie. The unit is hydraulically controlled, and is self propelled by a hydraulic motor with a spaced transmission obtaining speeds of 3 mph working and 12 mph traveling. Tie tongs used for holding the tie during the pulling and inserting operations are also hydraulically controlled.

This machine is equipped with a power jacking mechanism for use primarily in out-of-face work, as generally the track is surfaced after the timber is renewed.

Tie replacer.

The machine can be furnished with a spotboard, which consists of a telescopic sight, a fixed target attached to the machine, and an adjustable target which is used several rail lengths ahead of the jack. With this equipment the unit can be used in the surfacing operation.

Equipped with a 40-hp, water-cooled engine, this replacer is of welded steel construction. It has automatic rail dogs on the jacking head which engage the rail when the jacking foot engages the ballast, and requires no adjusting for different sizes of rail. The gross weight of this unit is 5000 lb.

Tie Renewer

This machine is designed to remove the old tie, cut the bed for the new tie, and install the new tie in a series of continuous operations. This machine's primary part is a flexible chain ram, consisting of a series of flat plates, which cuts the bed for the new tie as it pushes out the old tie. The machine may also be equipped with cranes for loading re-useable ties on tilt-body trucks, where they are banded into bundles and dumped along the track for loading. The machine is hydraulically operated and controlled by one man with the assistance of one laborer for the installation of ties and one laborer for the loading and banding of re-useable ties. It does not foul adjacent tracks while working, and may be used on inside tracks of multiple-track territory without fouling.

The sequence of operation consists of spotting the chain ram opposite the tie to be replaced, clamping the machine to the track, raising the track and machine slightly to clear the tie plates, from which the spikes have been previously removed by means of two lifting cylinders, lowering the ram roller guide track over the tie to be removed, pushing out the old tie and at the same time cutting a bed, engaging the new tie to the ram by means of a hook, returning the ram through the crib, thereby pulling the new tie into place square with rail, and then releasing the ram, roller track, lifting cylinders, and rail clamps ready for moving to the next tie. One laborer is used to drive the hook into the tie, engage the new tie to the ram, and to remove the hook from the ram after the new tie is in place. A chute is provided for returning the hook from the side of the machine where it is removed to the side of the machine where it will be re-applied. The other laborer operates the boom equipped with the hoist and tongs which is used to place the new ties in position, and to load re-useable ties removed from the track to a push truck coupled to the front or rear of the machine.

The machine is equipped with power jacks and transverse set-off wheels, lights, horn, hydraulic brakes and safety devices. It is powered either by gasoline or diesel engines driving three interchangeable hydraulic pumps. It is also provided with a plow for removing ballast from the ends of the ties in order to permit the ram head to engage the tie.

Tie renewer.

Hydraulic Tie Remover and Inserter

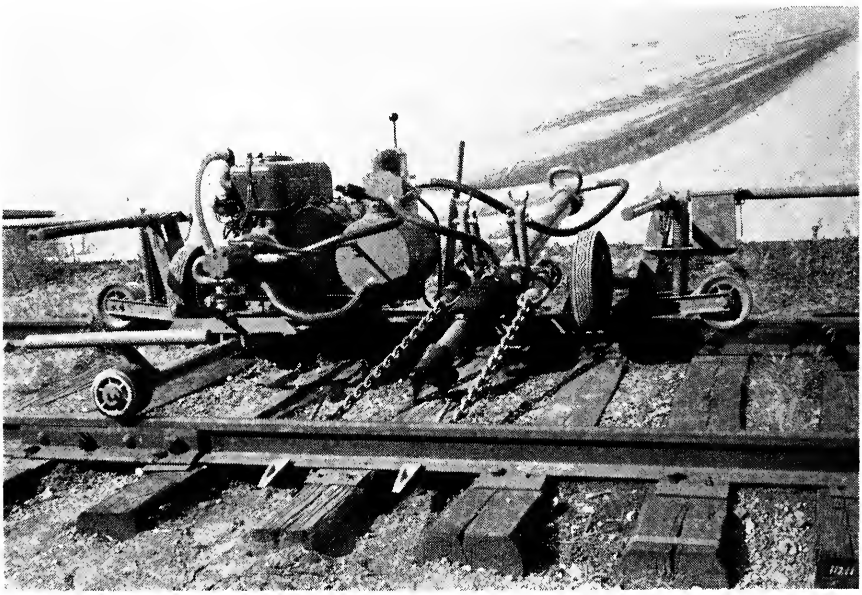
The first step in the use of this machine is to remove spikes and tie plates and to set the machine squarely over the tie to be removed. On the machine just above the rail is a ram with a full swivel mounting for easy action. On the ram head are two teeth which bite into the tie, and as hydraulic pressure is exerted a maximum force of 16,000 lb is developed in pushing the tie from under the rails. Removing one tie completely requires three strokes of the ram.

This machine is rail mounted, and when moving it from tie to tie one man releases and tightens the lever-operated rail clamp and shifts the valve that raises and lowers the machine onto the rail wheels. While in operation this same man guides the ram and regulates the control valve. The rail hooks that anchor the machine to the rail are placed on and removed from the rails by hand.

Rubber-tired pneumatic set-off wheels are part of this machine, and with the machine elevated on the rail wheels, the set-off wheels are swung down and locked with spring-loaded plungers. Retracting the rail wheels lowers the machine onto the set-off wheels. The engine and pump are on sliding bases, and the load can be centered for better balance in removing the machine from the track.

The power to operate the hydraulic system by direct drive through the pump is a 2-cylinder, 4-cycle, air-cooled engine. The unit is 9 ft ½ in long, 9 ft wide, 2 ft 7¾ in high, and weighs 1100 lb.

New ties are drawn into place under the rails by means of a new hydraulic tie inserter. When this machine is in working position it is clamped to the rails, and the new tie is pulled into the tie bed by a cable. Both ends of the cable are fastened to a drum, and the middle loop of the cable hooks over the far end of the tie to pull it into place.



Hydraulic tie remover.

Hydraulic tie inserter.

Before insertion the near end of the new tie is fitted with a nose plow and the far end with a tie shoe. This shoe has a groove for the cable and a handle to guide the new tie into place. To pull the tie in a straight line there are three rollers to aid in positioning the tie. The middle roller acts as an idler drum for the cable. The cable passes from the power drum down around the low drum and then out to the shoe on the far end of the new tie.

The cable drum is driven by a reversible hydraulic motor through a differential gear-type speed reducer and a jaw clutch. A 2-cylinder, 4-cycle, air-cooled gasoline engine drives the hydraulic pump. The rail clamps mentioned above and the rail wheels are actuated by hydraulic rams.

In moving this machine from tie to tie along the track, the rail wheels are used. When moving off the track three manually lowered rubber-tired set-off wheels are used. This machine is so designed that only two hydraulic control levers are necessary, one for the hydraulic motor and the other for rail clamps and rail wheels.

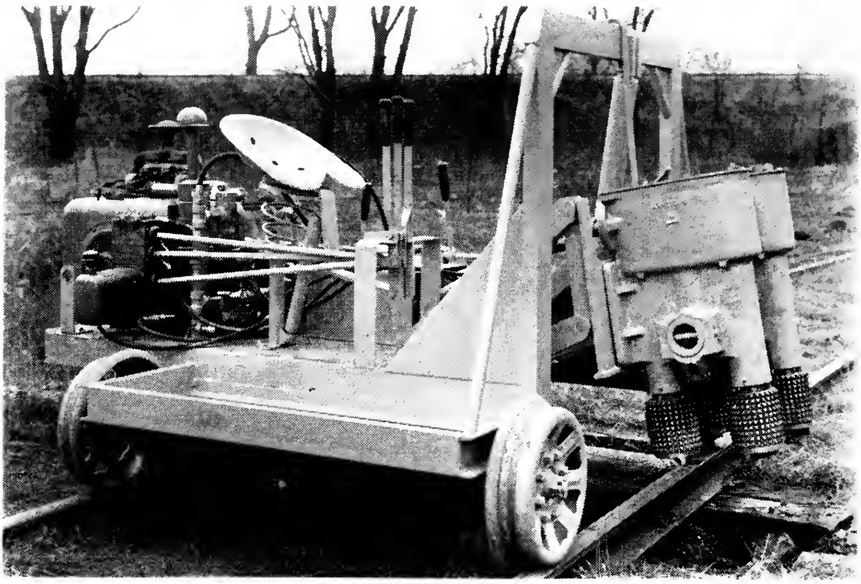
This machine is 6 ft 9 in long, 7 ft 6 in wide, 3 ft 7 in high, and weighs 1420 lb.

Tie Renewal Machine

The main frame of this machine is mounted on four flanged steel wheels for movement along the track. This frame supports five other main elements of the machine, four in a fixed position and one—the tie renewal head—in such a way that it can move up and down as required over ties being handled.

An air-cooled, 4-cycle gasoline engine developing 21 hp at 2000 rpm powers this machine. It is equipped with a standard 6-gal fuel tank carrying enough gasoline to run the machine for 3 to 4 hr at full load.

The mechanical power transmission system drives four tie-gripping rollers on the tie-renewal head. To do this, power from the engine is transmitted successively through



Tie renewal machine.

a clutch-reduction assembly and a speed-reducing chain drive into a reversing gear box. From this point it is carried through a pair of telescoping shafts equipped with universal joints into two cast-steel gear cases of the tie-renewal head and thence to the tie-gripping rollers.

Two steel transmission cases, four tie gripping rollers, and various operating mechanisms, all mounted on a base plate fastened on a boom pivoted to the main frame, make up the tie renewal head. Each of the two transmission cases encloses a group of gears which receive power from one of the two telescoping drive shafts operating more or less horizontally, and transmit it to the two vertical shafts which rotate the two tie gripping rollers in unison. One of these gear cases is secured to the movable base plate. The other slides back and forth as desired, supported by a horizontal guide bar fastened to it and passing through the first gear case. The sidewise movement of the second gear case is controlled by a double-acting hydraulic piston attached to the bottom of the two castings. By means of this piston, a tie can be squeezed between opposed pairs of tie-gripping rollers and then moved in or out at the operator's will. To take the thrust caused by rolling ties in and out, a boom-supported shoe straddles the rail head. Various shoes are provided to fit different weights of rail.

The hydraulic power transmission system consists of a pump, a single-acting cylinder for lifting the tie-renewal head, a double-acting cylinder controlling the pressure of the rollers against a tie, a hydraulic motor for indexing the machine from tie to tie, flexible hose and fittings connecting the components of the system, a set of control levers mounted directly in front of the operator, and a pressure gage mounted near the double-acting cylinder. The pump is mounted on the main frame and is driven by a belt drive attached to that side of the engine opposite the clutch This pump supplies hydraulic fluid to the entire system at a pressure of 1000 psi. The hydraulic motor which makes the machine self-propelling is located directly over the axle to the left of the operator. It drives this axle through a gear reduction unit which includes a flame-hardened steel pinion so mounted that it can be easily disengaged from the driving gear so the machine can be towed to and from the work site. There is developed approximately 6 hp from this hydraulic motor, which will move the machine quickly between ties or at a maximum speed of about 5 mph during longer movements.

This machine is equipped with a combined lifting device and turntable that is secured to the bottom of the main frame. It is operated by a hand-operated pump secured to the upright member of the frame to the right of the operator. By means of this device, the machine can be raised and turned either through 90 deg to remove it from the track at a grade crossing or motor car set-off, or it can be turned through 180 deg so as to place the tie-renewal head on the opposite side of the track. The weight of this machine is 3600 lb.

Tie Bed Scarifier

This machine is propelled by means of a hydraulic motor and is powered by a 4-cylinder, 4-cycle, V-type air-cooled engine equipped with an electric starter. It moves along the rail from tie opening to tie opening following the removal of the old ties.

Tie bed scarifier.

The scarifier can perform on track that has been raised from the old bed or non-raised track.

It has 3 hydraulically controlled revolving drums. As these drums revolve a new tie bed perpendicular to the rails and 10 ft long is dug to a predetermined depth. The only parts of the crib ballast not fully loosened and dug are the 2 sections immediately under the rails.

The drive for the revolving drums, which are equipped with removable teeth, is by a hydraulic motor through a speed reducer and three roller chains. Two hydraulic cylinders raise and lower the digging assembly, which is mounted in front of the machine.

A built-in turntable, operated by a hydraulic cylinder, is used in setting the machine off and on the track. The 2 hydraulic pumps are V-belt driven from the engine through a power take-off and have a manually controlled clutch. The entire scarifier is 11 ft 1 in long, 5 ft 1 in high, 10 ft 5 in wide, and weighs 5000 lb.

Report on Assignment 6

Maintenance of Automotive Vehicles

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This is a progress report, submitted as information only, and is a continuation of the study reported to the Association last year. This current study is confined to preventive maintenance of automotive vehicles.

"Preventive Maintenance" is a program which includes the proper operation, use, lubrication and inspection of automotive vehicles and is a means for the systematic detection and correction of incipient vehicle defects before they develop into major breakdowns. As a result of such immediate detection, vehicles may be maintained in a satisfactory operating condition. Such a program, faithfully carried out, will materially reduce the "out of service time" and the maintenance costs of vehicles.

It has been said that no automotive vehicle is in perfect operating condition but that its imperfections are often not detectable and are the cause, either directly or indirectly, of many major breakdowns. While a thorough and well organized system of preventive maintenance will not always detect these defects, generally speaking, they will be noticed and can be corrected before a major breakdown occurs.

The previous report of this subcommittee outlined, in a general way, the items to be given attention in connection with any preventive maintenance program. It also pointed out that any good, workable program of preventive maintenance must start with the operators of such automotive equipment if the program is to be carried through to a satisfactory conclusion. While it would be desirable to have a competent work equipment inspector check vehicles periodically and have competent repairmen make the necessary repairs, it must be understood that the main link in any good chain of preventive maintenance is the education and indoctrination of automotive vehicle operators so that they have complete understanding of the operation of their particular piece of equipment, as well as of the constant care, servicing and inspection that it requires.

Therefore, it is the object of this particular report to present, in the form of a circular or bulletin as shown below, a specific suggested program for preventive maintenance of automotive vehicles, which may be modified and changed to suit the conditions or requirements on any railroad.

THE NORTH AND SOUTH RAILROAD COMPANY MAINTENANCE OF WAY DEPARTMENT

Circular No. 1

SUBJECT: PREVENTIVE MAINTENANCE OF AUTOMOTIVE VEHICLES TO PREVENT MECHANICAL BREAKDOWNS

GENERAL

The purpose of this circular is to fix the responsibility for proper and adequate servicing, inspection, maintenance and repairs of all automotive vehicles to insure that proper attention is given this type of equipment to prevent or minimize mechanical breakdowns. The constant and periodic servicing, inspection and care of automotive vehicles are essential to the maintaining of vehicles in satisfactory operating condition for extended periods of time.

A. DUTIES AND RESPONSIBILITIES OF OPERATOR

The machine operator is the most important individual in the successful operation of any preventive maintenance program, as he is in the best position to detect minor defects or conditions which lead to vehicle breakdowns. It, therefore, is his responsibility to make whatever adjustments may be found necessary, if within his capabilities to do so, or to report defects immediately to his supervisor, work equipment inspector, or authorized repairman. Careless or improper driving practices can be a major factor in the development of mechanical failures which may occur in any vehicle and which can be exceedingly detrimental to any program of preventive maintenance designed to maintain vehicles in satisfactory operating condition.

Therefore, the operator of any vehicle must:

1. Familiarize himself with the particular vehicle he is assigned to operate by reading carefully the manufacturer's operating manuals and learning the individual peculiarities of his vehicle.
2. Learn and understand the capabilities of his particular vehicle and at all times make certain that it is not overloaded, taxed beyond its manual operational endurance, or subjected to treatment the machine was not engineered to withstand.
3. At all times comply with company, state, federal or local regulations concerning the load limit, speed limit and other such general regulations concerning the use and operations of automotive vehicles.
4. Be responsible for:
   a. Detection of defects which are indicated by oil, gasoline or water leaks; detection of faulty operation of parts or accessories; and detection of unusual noises, loose parts or anything out of the ordinary that is detectable by visual inspection or operation of the vehicle.
   b. Correction of the above mentioned defects or irregularities either by personal attention or by immediately calling them to the attention of his supervisor, work equipment inspector, or authorized repairman.
   c. Complete and periodic lubrication of the vehicle as called for by the manufacturer of the vehicle or as operating and climatic conditions may require.
   d. Changing of oil filter periodically as operating or climatic conditions may require so as to make certain that the crank case oil is being adequately cleaned and filtered at all times.

e. Periodic cleaning of the air breather and crank case breather cap as operating or climatic conditions may require to make certain that the air entering the carburetor and crank case is adequately filtered at all times.

f. Protection of vehicle cooling system against freezing, either by installation of an adequate antifreeze or the complete draining of the cooling system.

g. Cleaning of vehicle, both inside and outside, to insure that an accumulation of dirt, excessive grease and other foreign matter does not contribute to excessive wear and deterioration (nor impairs the operation) of the vehicle.

h. Maintaining crank case oil, cooling system water, battery water, and fuel levels, as well as maintaining proper tire air pressure, to help insure complete protection of the machine at all times.

i. Changing of transmission and differential greases at periods prescribed by the manufacturer of the vehicle or as climatic and operational conditions may require.

j. Repacking of wheel bearings at regular intervals as recommended by the manufacturer or as climatic or operating conditions may require.

5. Take the necessary precautions to:

a. Allow the engine a satisfactory period of warm-up at an idling speed before the vehicle is put into actual operation. During this warm-up period the operator should observe the ammeter, the oil pressure gage, and the water temperature gage to make certain that they are operating properly and that the engine is functioning satisfactorily. During this period both the foot brakes and the hand brakes should be tested to make certain of their proper operation. Also, during this period of warm-up, the windshield wipers, horn, headlights, tail lights, warning lights, turn lights and signal lights should all be checked to make certain they are in proper operating condition.

b. Check, while the vehicle is in actual operation, the various gages and indicators to insure that they are continuing to record properly and that the engine is in satisfactory operating condition. A drop in oil pressure reading or a radical change in the ammeter reading, as well as an increase in the water temperature reading above normal operating level, is usually an immediate indication of trouble. In the event that trouble is indicated during operation of the machine, either by radical changes in normal instrument readings or by unusual noises or vibrations, the vehicle and engine should be stopped immediately and not started again until the difficulty has been found and corrected (or it has been determined that the vehicle can be driven to a location where the necessary correction and repairs can be performed without further seriously damaging the machine).

c. Stop the machine as soon as possible in case of tire puncture or blowout to avoid further damage or destruction of the tire or tube and possible damage to the vehicle itself. Necessary warning lights and signs should be posted while the tire is being changed in order that driver and vehicle may be protected from other traffic.

6. In addition to the above listed responsibilities the vehicle operator, while vehicle is on grease rack being serviced, should:

a. Periodically check tires and wheels for possible tire and wheel damage and see that tires are being worn evenly. In the event of uneven wear on tires he should immediately arrange to have the wheel alinement checked.

b. Check for gasoline, oil, water and brake fluid leaks.

c. Check condition of muffler and tail pipe.
d. Check for loose bolts and nuts.
e. Visually check the electrical system for broken or frayed wires or poor connections that might lead to short circuits or other electrical failure.
f. Check frame, springs, braces, etc., for cracks and breaks.
g. Make any other check and inspection be personally feels is necessary towards the continuation of trouble free service of the vehicle he operates.

B. DUTIES AND RESPONSIBILITIES OF THE VEHICLE INSPECTOR

The work equipment inspector is also an important individual in any successful program of preventive maintenance and is in an excellent position to detect conditions and defects that may lead to eventual breakdown of an automotive vehicle.

Therefore, the inspector must:

1. Familiarize himself with the many and varied vehicles that come under his jurisdiction.
2. Learn and understand the operation and capabilities of the various pieces of automotive equipment under his jurisdiction.
3. Make regular periodic checks and inspections of automotive vehicles under his control to determine that they are being properly used and cared for, and at those intervals see that all defects he notes are properly repaired and corrected.
4. Make certain that all defects reported by the vehicle operator are repaired and corrected.
5. Periodically check the actual operation of automotive vehicles by their operators to make certain that the vehicles are not overloaded or abused beyond their operational capabilities, and that the drivers thereof are complying with company, local, state and federal regulations concerning the operation of automotive vehicles.
6. Check each vehicle after repairs thereto have been completed to make certain that all defects and other allied work have been repaired properly.
7. Periodically indoctrinate all automotive vehicle operators with the proper methods of preventive maintenance, use and care of the vehicle they are assigned to operate. He should particularly explain the operation of particular automotive vehicles to any new operators, making certain that they understand the operation of the machine assigned to them and understand the use and care the machine should receive.
8. Handle all other inspections and allied matters that are logically his responsibility.

C. DUTIES AND RESPONSIBILITIES OF AN AUTOMOTIVE REPAIRMAN

The work equipment mechanic is another very important individual in a successful program of preventive maintenance. He also is in an excellent position to detect conditions and defects that can lead to serious vehicle breakdowns and can readily tell whether a vehicle is being properly cared for with respect to use, operation and servicing.

The work equipment mechanic must:

1. Handle in a workmanlike manner all defects and repairs reported to him by the vehicle operator or work equipment inspector.

2. While either servicing, lubricating or repairing an automotive vehicle, handle and correct all minor defects and deficiencies he notes. He should check and clean the spark plugs, check the fan belt, check the condition of the battery, check the water level in the radiator, check all oil and grease fittings, check tire air pressure, and make all other visual preventive maintenance checks to determine that the vehicle is in proper operating condition.
3. Immediately report to his supervisor or work equipment inspector any case where, in his opinion, he feels that the machine is not being cared for properly by its operator or has been misused or abused.
4. Immediately notify his supervisor when he is confronted with repairs to a vehicle that he is not able, or does not have the necessary tools and equipment, to handle.

Report on Assignment 7

Machinery for Unloading, Distributing and Dressing Ballast

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This is a final report, submitted as information.

The availability of adequate equipment for the shipment and distribution of ballast is of primary importance. The equipment generally used for these operations includes the following:

Spreader—Ditcher Car

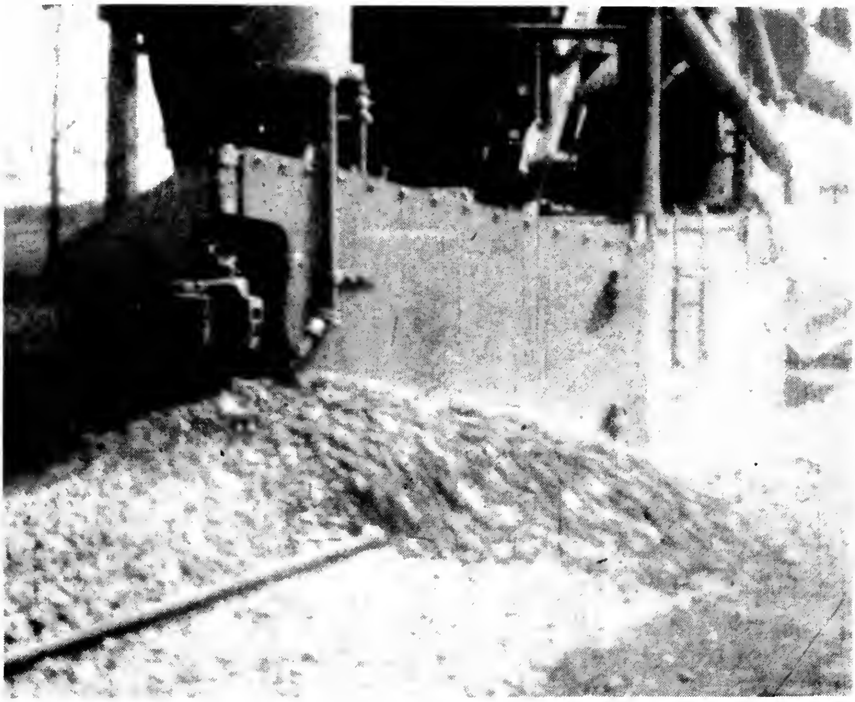
This is a heavy, rugged, on-track machine designed for a multitude of maintenance assignments, including ballasting programs. It is currently constructed to sustain the thrust of any type of locomotive that may be used in work train service.

With its versatile front plow and adjustable ballast section blades, the machine can plow and flange ballast from between the rails at 1-in increments from level with to 7 in below the top of rail, to either or both sides of the track as desired at the same time shaping existing ballast or dressing freshly applied ballast on the shoulders. The spreader-ditchers are also used extensively to cut foul ballast away from the ends of ties.

Since the ditcher template wings are designed to cut the true roadbed cross section, much additional work can be accomplished simultaneously with the ballasting program, to promote good surface drainage and present a more sightly and well attended property. With the combined spreader–ditcher and bank sloper wings, the subgrade or berm can be levelled, fills dressed, and drainage ditches cleaned or established in cuts and low embankments. The machine may also be used to carry excess material from cuts, widening and contouring them in one operation—the excess earth and other material being used to widen and reinforce the adjacent fills.

The type of spreader–ditcher in general use is pneumatically controlled by one operator, the working pressure being taken from the main reservoir of the locomotive. The machine has a total spread with both wings of 40 ft or more, with a vertical range from 1 ft above to 3 ft below the top of rail.

While all previously constructed spreader–ditchers are pneumatically operated, the manufacturer has undertaken an extensive re-design and improvement program. While



Nose of spread-ditcher being used to shape ballast prior to tamping operation.

the details of this work are not available at this time, it is proposed that the operation of the new machine will be independent of the locomotive, except for propelling power. Other innovations are being planned to increase the machine's effectiveness and versatility.

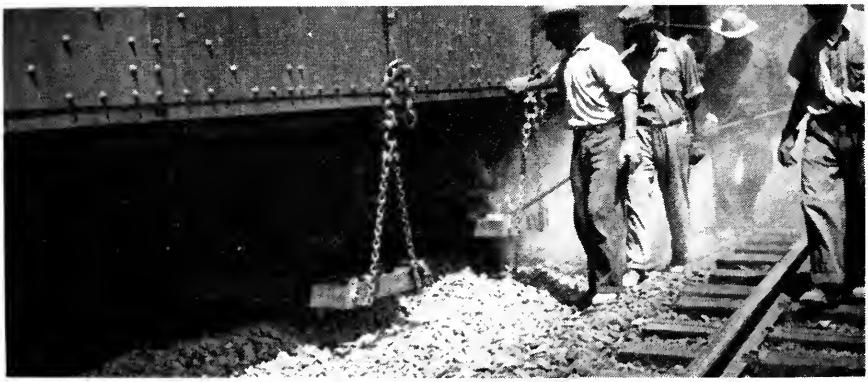
Special Ballast Cars

Special ballast cars of the hopper-bottom type are designed to unload through controlled doors. The hopper-bottom ballast car has a body with a sloping floor sufficiently steep to discharge the ballast to the side or center of the track in the quantity required. The operator walks alongside the car working the operating handle which controls the flow of the ballast. The controls for flow of the material from the center hoppers can be operated from either side of the car, permitting the operator to work on one side of a train, and the controls for unloading the side hoppers are located on their particular side, which arrangement allows the operator to view the unloading operation at all times. The hopper unloading controls on modern ballast cars are of the worm and gear type and are manually controlled, thus permitting the unloading of any portion of the contents of the car. Although it is not practical to close the hopper doors after they are once opened during unloading operations, it is possible to tighten them sufficiently to pinch stone ballast or similar coarse material and prevent its further flow. Some cars have small pockets at the end from which small quantities may be delivered at the sides in a manner known as "peddling." Although special ballast cars are designed

Special ballast cars of the hopper-bottom type.

Special ballast cars.

Ballast unloading pan.



Hopper-bottom car with ballast pan slung below hopper, being used to unload crushed stone ballast.

for ballast service, they are suitable for hauling coal, concrete aggregates, sugar beets, ore and similar products.

Another type of special ballast car is so constructed that it may be converted from the flat bottom, side unloading type to the V-bottom center unloading type. When used for center unloading it is equipped with a longitudinal V-type hopper which extends the full length of car between the trucks. The amount of ballast unloaded is controlled by the opening of the V-bottom, which is actuated by a ratchet device at the end of the car. This type of car, with end gates removed and converted to flat bottom, and equipped with steel aprons, is used extensively by some railroads to distribute gravel ballast with lidgerwood and ballast plows.

Hopper-Bottom Cars

Hopper-bottom cars of the type regularly used in revenue service are designed with floors sloping from the ends and sides to one or more hoppers which will discharge the load by gravity through the hopper doors. When used for ballasting work, continuous distribution is effected by moving the train slowly as successive cars are unloaded. The ballast may be cleared from the rails by a tie or timber drag placed in front of the rear truck wheels. Hopper cars are useful for unloading between the rails, in back filling tracks which have been raised, or immediately preceding the raise. Specially designed ballast pans slung below the hopper openings are extensively used to distribute the ballast uniformly for light surface lift operations.

General Purpose Cars

General purpose cars of the gondola type, with drop-bottom doors, controlled by a ratchet device at the end of car, are sometimes used to unload ballast at the ends of the ties. Because of difficulties in controlling the amount of ballast unloaded, they are not as suitable as the other cars herein referred to.

Air-Operated Side Dump Cars

Modern air-operated dump cars are built of high-tensile, low-alloy steels to combine strength with light weight. They vary from 23 ft 8 in inside length to 41 ft, and in weight-carrying capacities from 80,000 lb to 154,000 lb. Loads vary from 20 to 50 cu yd struck capacity, and 30 to 70 cu yd heaped capacity. Air for dumping the cars is supplied from the train line to air reservoirs on each car, thence to air-actuated piston cylinders.

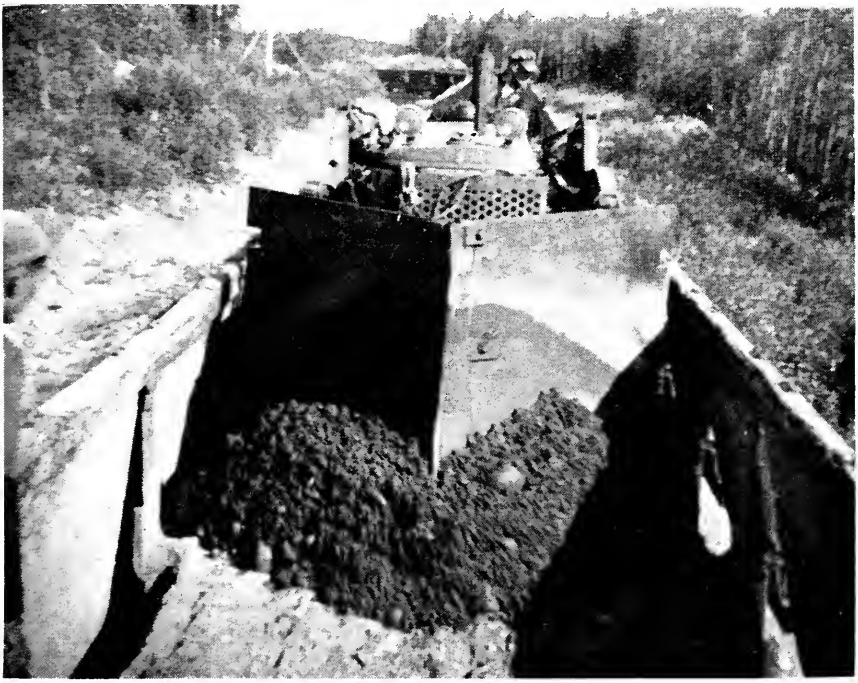
Practically all dump cars are now of the side pivot or down-turning door type, and are lower than the old center hinge lift-door type. The new designs have eliminated locking mechanisms and provide cars of simple construction which are easy to maintain, since they consist essentially of the side-tipping bodies resting on draft beams and large diameter air cylinders to provide dumping to either side. Doors are moved outward and downward, and returned to their normal positions in righting, by means of a simple mechanism synchronized with the movement of the car body.

Air dump cars are not suitable for unloading ballast for surface lifting; they are used extensively to unload ballast or pit material in bank restoration programs. The down-turning door acts as a chute or apron to keep material being unloaded clear of ballast shoulder section. These cars are also used to unload fill material or ballast for the construction of adjacent tracks. In this work a spreader is used to level the material thus unloaded. The cars may be dumped individually, or the entire train operated as a single unit.

Lidgerwood Cars

Lidgerwood cars are extensively used by some railways. They each consist of a steam-powered winch having a line pull capacity of 60 tons, with a large diameter drum secured to a railway car, using 1400 ft of 1½-in wire rope to haul a plow through gondola-type cars with end doors removed and equipped with steel apons. The steam supply is obtained from a special coupling arrangement at the front end of the locomotive. The side doors of the ballast cars are opened by means of a release lever which allows the doors to swing outward and ballast is plowed from the cars in the desired quantity. Three types of plow are used: right, left and center. The right or left-hand plow will unload the ballast to the right or left-hand side, while the center plow will unload the ballast equally on each side of the track.

Lidgerwood car and ballast plow.



Ballast unloading plow mounted on a bulldozer.

Plow-Equipped Bulldozers

Bulldozers equipped with plows are used to unload ballast from special ballast cars of the gondola type with side doors, equipped with steel aprons. It is reported that while this equipment does not remove the ballast as close to the floor of the car as does the ballast plow, the performance is very satisfactory and the speed of unloading is approximately that of a lidgerwood operation.

Ballast Regulator

A machine for regulating and plowing ballast is operated by one or two men and is provided with a turntable for removal of the machine from the track or permitting it to be turned to operate in the opposite direction. It is powered with a 100-hp gasoline or diesel engine with a 4-speed forward and reverse transmission, and is equipped with a 4-wheel drive. Adapted to the power unit are ballast regulating wings for shaping the ballast shoulder and a V-type plow for regulating and distributing ballast in the center of the track and outside of rail to the ends of the ties. The ballast wings and plow are ajdustable to fit any standard ballast section.

This machine is a versatile unit and can be used ahead of the surfacing gang for regulating and distributing the ballast evenly, filling in all empty cribs and removing excess ballast from the center of the track, placing it on the ballast shoulder for distributing and final dressing. Sufficient ballast properly distributed is left in the track to make the desired raise for the tamper. After the surfacing operation is performed, the machine is used beind the surfacing gang to regulate and distribute the shoulder ballast and to shape the ballast shoulders and perform the final dressing of the track.

Machine for regulating and plowing ballast.

Another view of machine for regulating and plowing ballast.

The regulator may be placed ahead of a tie renewal gang to cut away ballast to the bottoms of ties, or 2 in below, if desired, in order that old ties may be removed and the new ties installed in a more satisfactory manner. After the tie renewals have been made, the machine is used to pull the ballast back to the tie ends, shaping it and dressing the track to the standard ballast section.

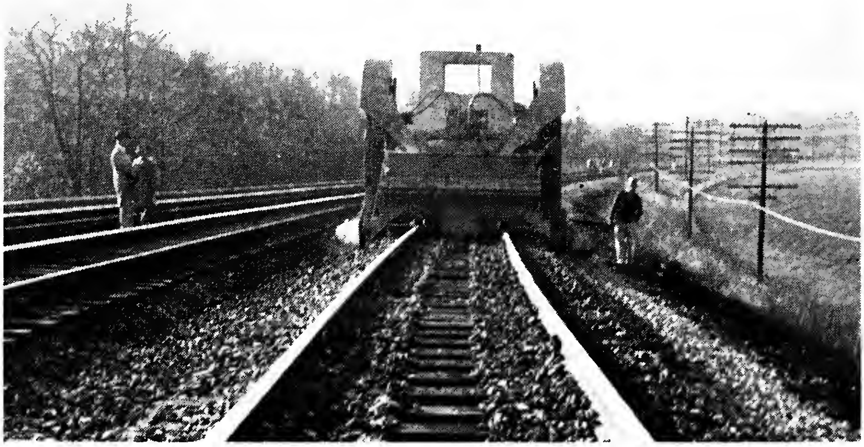
Under traffic, ballast generally tends to work away from the tie ends or beyond the toe line of the ballast section. To correct this situation the machine is utilized to reach out beyond the toe line and reclaim this ballast, pulling it up on the ballast shoulder and back to the tie ends and dressing the track. The ballast wings are so designed that the ballast is at all times pulled back into the track and thus can be saved. This machine can be equipped with a broom attachment to clean ballast thoroughly from the tops of the ties.

Ballast Distributor

A ballast distributor has been in service for more than two years, which provides controlled distribution of ballast for tamping and permits tie installation without interference from ballast unloaded ahead of a gang. This machine picks up ballast from the inter-track space or border by means of a bucket-type conveyor and loads it into a hopper. The ballast is then distributed in the cribs and at the ends of the ties through six adjustable openings in the hopper. The adjustment of the openings provides for the desired quantity of ballast to be placed on each side of each rail, as well as at the ends of ties. The hopper itself may be raised or lowered to give the desired depth of ballast.

Where track is to be raised and tied, the ballast may be unloaded in advance of the gang in the inter-track space and on the shoulder. The ballast does not then interfere with tie renewals and may be placed by the distributor exactly as desired for tamping after tie renewals have been made. By distributing the ballast evenly, it is said that a more uniform mechanical tamping of ties is obtained. The machine is also equipped with wings and levelling blades for dressing the ballast after work has been completed, and is also able to transfer excess ballast directly from one side to the center of track or opposite side by adjustment of openings in the hopper. If desired, excess ballast may be loaded in the hopper and carried to a point where needed. Adjustable deflecting blades in the hopper are used to distribute ballast in the hopper so as to compensate for irregular unloading of ballast. A ballast chute between the conveyor and hopper is provided with a screen which separates dirt from the ballast so that clean ballast is placed on the tamping area.

The machine is operated by one man through a bank of hydraulic control valves located in an enclosed cab. It is powered by either a gasoline or diesel engine, driving three hydraulic pumps. The machine is mounted on flanged wheels driven through a chain drive and transmission by a hydraulic motor. The travel speed of the machine is advertised to be up to 24 mph. When working, one hydraulic pump is used to furnish power for driving each bucket conveyor, with the third pump being used for travel, and conveyor or hopper adjustments. When not working, all three pumps may be used



Ballast distributor.

for traveling. The conveyors are independently controlled so that they may be raised or lowered while working as the ballast section varies. The machine is equipped with hydraulic brakes and a sanding device. Hydraulic jacks and transverse flanged wheels are also provided for removing the machine from the track.

The machine does not foul adjacent tracks when working. The conveyors may be tilted for loading in a car to keep within the required shipment dimensions.

Conveyor-Type Bucket Loader

A conveyor-type bucket loader consists of a crawler-mounted chassis made up of structural plates and angles to support a bucket elevator boom, drive and transmission machinery. The foot or feeding end of the boom is equipped with a spiral feeder which assists in feeding the material into the conveyor buckets as the machine moves forward. The material is conveyed to the head of the boom and discharged through a side chute. The chute is adjustable and can be swung in an arc of approximately 180 deg. Additional lengths of side chute can be applied to discharge the material a greater distance where required. It is controlled by one man from an operator's platform located on the

Conveyor-type bucket loader being used to unload ballast.

side of the machine. A 38-hp gasoline engine is used to drive the conveyors and propel the machine.

The conveyor-type loaders are used for unloading bank restoration material, such as pit-run gravel and cinders from flat-bottom open-end gondola cars. The machine is narrow enough to permit the unit to crawl inside the cars, picking up and unloading as it moves from one car to another. Two machines or more can be used in a train, unloading on opposite sides, as required. While this machine will not unload ballast as fast as many other methods, it has the advantage of being able to distribute the exact amount of material required without spilling and fouling the rock ballast section, as the discharge chute places the material as required on the bank or berm.

In handling pit-run gravel with these machines it is good practice to select pit material that is reasonably free from large stones. Stone larger than 4 in. in diameter will damage the machine parts, such as feeding spirals, buckets, etc., as they are picked up and carried into the conveyor, jamming the mechanism and sometimes breaking the headshaft. While the boom is equipped with a spring-loaded overload release sprocket to protect the conveyor parts if they should jam, the frequent releasing of this device will eventually fatigue the material in the headshaft, causing it to break.

Report on Assignment 8

Automotive Trailers For Transporting Work Equipment

C. T. Blume (chairman, subcommittee), G. R. Collier, F. L. Horn, Haynie Hornbuckle, Herbert Huffman, J. A. Mann, F. E. Short, R. S. Stephens, G. M. Strachan, M. C. Taylor.

The present application of automotive trailers by railways in transporting work equipment is moderate. Very few own equipment of this kind, and the consist includes only a small number of standard types. Accordingly, your committee has made an effort to include both the potential and the realized use of trailers for transporting work equipment.

Special permits must be obtained in all cases where the size or weight, both axle and gross, exceed the ordinary limits set forth for movements on the highways of the state involved.

Standard types, with possibly a few exceptions, are adaptable to the service requisites. The standard types will normally effect a reduced investment and maintenance expense and have a reasonable trade-in value that cannot normally be realized in the case of highly specialized trailers. The committee recommends the standard types when the applicability permits.

There are two general classes of trailers—semi-trailers and trailers (full trailers)—each of which may be divided into numerous subclasses. This report describes the types believed to be best adapted to the highway movement of work equipment:

1. Semi-trailer Types

The pneumatic-tired semi-trailer is more maneuverable than the trailer and is not restricted in type by any state. The standard types are tilting platform, rear loader, folding or arched gooseneck, low bed, float or oil-field platform, and catwalk. There are other designated names for the afore-mentioned types, but the terminology used is that generally accepted.

a. *Tilting Platform Type*

This type is available with a single or tandem axle and single, dual or multiple wheels. The platform may be either over or underslung and is designed for long hauls at high speed and full capacity. This type fills the requirements at a minimum investment for transporting roadway machines and work equipment within the weight capacity and dimensions of the platform load area. The unit is especially desirable for moving small equipment. Although semi-trailers of this type have been developed with a very low gross vehicle weight rating, the standard units will have an approximate G.V.W. rating of from 3,000 to 40,000 lb and an unladen weight of from 1,000 to 7,500 lb. The maximum platform loading area varies from 8 by 10 ft to 8 by 18 ft, with deviations. This type is advantageous because of its easy loading feature and the low or underslung design is favored when conditions permit. Road clearance and overhead obstacles are of primary importance in selecting either design.

b. *Rear Loader Type*

This type is available in the drop or level platform design and is a heavy equipment transporter. The G.V.W. rating of standard units is from 24,000 to 120,000 lb and the unladen weight from approximately 5,700 to 18,600 lb. The platform load dimensions range from 8 by 13 ft to 9 ft 6 in by 16 ft. This type is desirable in hauling equipment of considerable height when overhead obstacles are encountered. The large size units may necessitate special highway moving permits. Daylight moves will also be a requisite in a number of states.

c. *Folding or Arched Gooseneck Type*

The folding gooseneck type will usually be of the drop platform design, i.e., a front end or nose loading unit with low road clearance. The equipment is easily loaded and greater equipment height is possible. The arched gooseneck type is similar to the folding type, but is either a rear or side loader. The G.V.W. rating is from 10,000 to 125,000 lb with the unladen weight ranging from 5,600 to 20,000 lb. With a platform loading area of from 8 by 12 ft to 9 ft 8 in by 35 ft, the unit is capable of moving heavy equipment. Special permits for highway movement are again involved in the large dimensioned capacity units of this type.

d. *Low Bed Type*

General hauling service, wherein minimum road clearance is possible, makes this unit a very versatile equipment transporter. The road clearance is only approximately 8 in and its use is definitely confined to very favorable highway conditions. The standard units now available have a G.V.W. rating of from 22,000 to 64,000 lb with an unladen weight of 5,200 to 11,800 lb. The platform is of the drop type and the machine can be loaded either from the rear end or from the side. The load area is 8 ft by 14 ft.

e. *Float or Oil Field Platform Type*

This trailer is possibly the most commonly used type because of its roadability. Its road clearance is such that very exacting conditions, or even off-road operation, seldom restrict its use, but overhead obstacles are a problem. Nose loading is reasonably easy when the trailer is uncoupled from the highway tractor. The trailer is not suitable in transporting crawler cranes and other work equipment of similar height. However, it is a desirable unit for transporting crawler tractors and other pieces of work equipment of similar dimensions, especially when long hauls are encountered. The G.V.W. rating of from 16,000 to 54,000 lb, with unladen weight of from 7,650 to 13,000 lb, is the approximate weight range. The platform, with very few exceptions, is 8 ft wide and special units are available exceeding the maximum standard length of 32 ft.

f. *Catwalk Type*

This semi-trailer is designed for one purpose—the transportation of medium-sized crawler tractors. The road clearance may be termed medium and is approximately 14 in. The G.V.W. rating is from 14,000 to 22,000 lb, with an unladen weight of approximately 3,000 lb. The loading area is unique, consisting of two running boards with a raised center platform.

2. Trailer Types

This type is also known as a full trailer. Its service should be confined to terminal operations or very favorable road conditions. The capacity varies with the rate of speed. This type is not very suitable, because of its adverse maneuverability, and safety hazard on grades or slippery roadways and similar road irregularities. This type is illegal in the states of Alabama, Connecticut, Iowa and Kentucky, and other states may enact laws prohibiting the type on their highways. With the exception of the tilting platform type trailer, the semi-trailers can be readily converted to the full trailer type by use of a front axle assembly or converter dollies.

Trailer brakes are not required in a number of states, unless the G.V.W. exceeds 3000 lb, although some states do require brakes when the G.V.W. exceeds 1000 lb. Power brakes are recommended on all semi-trailers and trailers, irrespective of the weight capacity. The trailer brake system must coincide with the truck brakes.

Report on Assignment 10

Work Equipment Hydraulic Systems

S. H. Knight (chairman, subcommittee), R. E. Berggren, B. E. Hayes, W. F. Kohl, H. C. Nordstrom, J. E. Reynolds, H. A. Thyng, F. E. Yockey.

This is a final report, submitted as information.

For many years the operation of any unit of work equipment depended upon a conventional type of apparatus, consisting of a prime mover which furnishes the energy, and a series of shafts, sprockets, gears, chains and belts to transmit this energy to the working portions of the machine. In recent years there has been a marked trend toward the use of hydraulically operated transmission systems. At present there are so many machines on the market which operate hydraulically that it was considered desirable to acquaint railroad personnel with the existence of such machines, how they are constructed, how they operate, and how they should be maintained. This report represents an effort to satisfy the demand for information regarding machines which depend upon hydraulics for their operation. It omits information on fluid clutches and torque converters, which should be covered as separate subjects.

A modern hydraulic transmission system is essentially a product of the war years from 1940 to 1945, and the post-war years, during which its development was given tremendous impetus. It has been said this development is still in its infancy. Whether or not that is so, hydraulic systems are competing more and more favorably with mechanical, pneumatic and electrical transmissions, and we may expect to see greater use made of them in the future.

A hydraulic transmission system is a means of transmitting power hydraulically and consists basically of a reservoir for the fluid, pump and prime mover to operate it for circulation of the fluid under pressure; a selective valve, or system of valves, to direct and control the flow; supply and return tubing or piping; and actuating rams or rotating motors to convert the fluid pressure into mechanical energy. Since the terms "hydraulic fluid" and "hydraulic oils" both refer to petroleum oil and mean the same thing, the terms hereafter will be used interchangeably.

The reservoir for fluid should not only be large enough to supply the system, but must also have adequate capacity to permit of cooling the fluid before recirculating it, unless an oil cooler is used. The consensus is that the oil temperature should not exceed 120 deg. The reservoir should be equipped with an air vent to which should be fitted an air filter capable of screening out all airborne dust and dirt, and an oil screen should be installed in the suction line between the reservoir and pump. Some manufacturers also use an oil filter.

The pump, which is nearly aways of the rotary type and usually operated by an internal combustion engine as a prime mover, may be any one of three types, or modifications thereof, namely:

Gear type for large volume and low to medium high pressures where some pump slip is not objectionable.

Vane type for moderate volume and low to medium high pressures where no internal slippage and pump efficiency are important.

Piston type for low volume and low to very high pressures where no internal slippage and high pump efficiency is necessary.

Vane and piston-type pumps may be either of variable or constant capacity, depending upon the internal construction of the pump. Gear pumps have a constant capacity and are usually of the spur-gear type. They are less accurate, cost less and operate at lower pressures and are inclined to offer shorter life and require more maintenance than do vane and piston-type pumps. Briefly, a vane-type pump consists essentially of a radially slotted rotor that is eccentric to a surrounding ring. In the rotor slots are close fitting vanes free to move in and out as the rotor revolves. A variable volume of fluid may be secured by changing the degree of eccentricity between rotor and ring. Such pumps are more accurate than gear pumps.

Piston-type pumps are either radial or axial and consist of a rotating cylinder block assembly with pistons located either radially around the shaft or axially (parallel) to it. The volume of fluid pumped may be fixed or variable, depending upon the degree of angle between the center line of the cylinder block and the drive shaft. If the angle is fixed, the pump is of the constant-delivery type; if it is adjustable, the pump is of the variable-delivery type. Piston-type pumps provide high pressures, are extremely accurate and are increasing in popularity.

Accumulators are used in some hydraulic transmission systems. An accumulator is essentially a fluid pressure storage chamber in which the potential energy of an incompressible fluid under pressure can be stored against some dynamic force to do useful work when called upon by the requirements of the hydraulic circuit in which it is used. This dynamic force is actually a force which will push the fluid out of the accumulator into the hydraulic system as required.

In addition to storing fluid energy for instantaneous use when the system calls for it, the accumulator also serves to smooth out pressure surges and prevent shock pressures developed in the system from damaging the circuit components.

Nitrogen gas under high pressure, enclosed in a flexible rubber bag or piston or other container within the steel or aluminum container, is used as the dynamic force.

The driven members of the system are either rams, which may be single or double acting where linear or reciprocating motion is desired, or motors where rotation is desired. The construction of a fluid motor is quite similar to that of a pump. A motor may be either gear, vane or plunger type. Theoretically, almost all designs of pumps may be used as hydraulic motors. Actually, there are only a few commercially successful designs in use because of inherent hydraulic or mechanical reasons, not the least of which is that of unbalanced loads on intake and discharge sides of the pump, resulting in pressure binding. Motors are used for propelling purposes and for the operation of conveyor belting, V belts, chains and sprockets used with endless bucket lifts, and similar installations where rotation is necessary.

Between the drive member and the driven member is the distribution system of supply and return piping or tubing with various control valves, many of them automatic, and it is here where simplicity sometimes stops and complexity takes over. Supply and return lines with couplings, seals, rings, pressure relief valves and other control and operating valves must be designed to withstand pressures that are frequently in excess of 1000 psi, and may go as high as 5000 psi. Materials used in the distribution system should be only of the best quality obtainable and may be either steel tubing or pressure hose, depending upon the need for flexibility, initial cost and other service factors.

The operation of a unit of work equipment with a hydraulic transmission system is very little different than that of a machine with a conventional drive, except that more care must be taken in preparing it for operation. Thought should be given as to the fluid to be used, which should be of a good grade and must be absolutely clean, since the admission of even fine particles of dirt will cause difficulty. To provide for initial cleanliness, the hydraulic oil should be carefully screened before it is placed in the reservoir.

Field maintenance of hydraulic systems must be done with more than the usual amount of care, primarily to prevent grit and dust from entering the system. Dismantling and re-assembly of the oil lines, strainers and filters, if any, must be done in an approved manner, with emphasis placed on cleanliness. Filling of the reservoir should be done most carefully in order to avoid contamination of the new oil.

From both a practical and economical standpoint the shop repairing of hydraulic pumps, motors, rams and valves must of necessity be limited to a careful examination of the parts for visible or measureable wear and to the replacing of worn parts. Service tests may be conducted to check the speed of rotating and reciprocating parts for smoothness of operation and to determine if there are any defective and leaky rings, seals, couplings, etc.

However, because of the many different types and kinds of hydraulic equipment in use and the complete lack of standardization that prevails today, it is considered neither practicable nor economical for the owning railroad to set up the elaborate and costly equipment that would be necessary to conduct volumetric and slippage tests on pumps, motors, rams and valves. Such work, together with the reconditioning of certain worn parts, can still best be done by the builder.

The need for cleanliness and care to be used in repairing and assembling the equipment must be impressed upon the shop repair men, since the parts are built to extremely close tolerance with a high degree of polish and will be damaged by even minute scratches. Supply and return lines should be pre-cleaned to insure removal of dirt, grit, scale, metal or other foreign matter.

Selection of the hydraulic fluid or oil to be used in a hydraulic transmission system must be done with care. Unfortunately, there are many differences of opinion on this subject, and the user must depend almost entirely upon the recommendations of the manufacturer of the machine in question. One of the cardinal requirements for a hydraulic oil is that it must have the correct viscosity and adequate lubricating qualities because the moving parts in the hydraulic system are lubricated entirely by the hydraulic oil. Temperature changes where a machine is to be used have a marked effect on the grade of oil to be used and will be the determining factor in the pour point, which should be 5 deg F lower than the lowest ambient temperature. It appears that the oil should be of good quality, with a viscosity of SAE 10 for cool or cold weather, and SAE 20 for summer operation in high temperatures, and should retard foaming, oxidation, rust and corrosion. Oils containing high additives or detergents (heavy-duty types) commonly employed in motor oil as dispersing agents of engine deposits, such as lead salts, should not be used. For special conditions or extreme low temperature operation it is suggested the fluid problem be referred to the refiner, manufacturer or pump builder. Suggested specifications for hydraulic oils follow, but it should be understood that these are for average conditions of use only and do not cover all types of pumps and motors.

Gravity	26.0
Flash	385
Fire	435
Viscosity S.U.S. @ 100 deg F	100–300*
Viscosity index	75 to 90 or above
Pour point	—15° to —25°
Conradson carbon	0.10%
Neutralization No.	0.05
Demulsibility	125 or less

* Depending upon make and type of pump and season of year.

The type of hydraulic system used depends entirely upon the conditions involved and the work to be done. There are many types of work equipment which employ hydraulic transmission systems in one form or another. Some of these are:

Hydraulic spike pullers—pump and rams.
Cribbing machines—pump and rams.
Power ballast jacks—pump and rams.
Ballast screening and cleaning equipment—pump, rams and motors.
Ballast maintenance cars—pump, rams and motors.
Dump trucks—pump and ram.
Most set-off apparatus in various machines—pump and rams.
Some makes of crawler and truck-mounted shovels—pump and motors.
Bulldozers—pump and rams.
Loaders and hauling equipment—pump and rams.
Industrial tractors and some mowers—pump and rams.

Some of the advantages claimed for a hydraulic transmission system are that it is simple in principle, flexible yet smooth and vibrationless in operation, and reliable. It seems especially desirable for operation of auxiliary power take-off apparatus on machines that may be remotely located from the prime mover, which would otherwise involve a complicated hook-up of sprockets, chains, gears and shafting; also for any use where linear or reciprocating motion is necessary.

Hydraulic systems have been found to have certain disadvantages, some of which are:

1. The difficulty of installing couplings, tubing, seals and rings to hold against hydraulic pressures up to 5000 psi.
2. The difficulty of maintaining a system that must be clean and free of dirt.
3. The difficulty to the average man on the ground of localizing trouble when it does occur. (i.e. manufacturers should provide connections and valves for insertion of pressure gages at key points on the lines for use in locating trouble.)
4. Maintenance of tubing or hose that may have deteriorated from use or age, and the difficulty of getting correct replacement parts. Many low-pressure hoses and connections resemble the high-pressure types and may intentionally or unintentionally be substituted. Quality, not price, should be the governing factor in purchasing. Less costly supplies which look the same may be more costly in the end. Split or cracked lines or leaky seals and rings can, if not detected, cause serious damage to the system. It is essential that "O" rings be of the proper type for commercial oils and are not the so called AN type used in military specifications for special military oils.
5. Seals and rings are inclined to develop pressure leaks.

Hydraulic transmission systems are fundamentally sound and, in many instances, offer advantages in power transmission that cannot be otherwise duplicated. However, standardization of design is needed, and the fact should be recognized that there are many installations of hydraulic systems on machines where energy can be transmitted more simply and directly by conventional mechanical linkage, and on which the maintenance is less costly.

Report of Committee 28—Clearances

A. M. Weston, *Chairman,*
C. O. Bird
E. S. Birkenwald
B. Bristow
W. S. Campbell
A. B. Chapman
S. M. Dahl
J. W. Darby
W. T. Davis
D. H. Dowe
J. E. Fanning
J. E. Good
R. L. Goss
J. E. Greenlee
A. R. Harris
W. F. Hart
J. D. Hudson
C. F. Intlekofer
J. D. Jardine
M. L. Johnson
W. P. Kobat
F. Martin
E. E. Mills
B. F. Nauert
A. G. Neighbour
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E. R. Word, *Vice Chairman,*
C. E. Peterson
W. F. Pohl
A. D. Quackenbush
A. J. Rankin
W. S. Ray
J. C. Scholtz
J. F. Smith
J. E. South
O. W. Stephens
R. H. Taylor
J. W. Wallenius
H. G. Whittet, Jr.
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   No report.

2. Clearances as affected by girders projecting above top of track rails, structures, third rail, signal and train control equipment, collaborating with Signal and Electrical Sections, and with Mechanical and Operating-Transportation Division, AAR.

   Progress report, presented as information .... page 558

3. Clearance diagrams for recommended practice, collaborating with committees concerned.

   No report.

4. Compilation of the railroad clearance requirements of the various states.

   Report includes as information a tabulation of the clearance requirements of the various states, revised to November 17, 1954 .... page 558

5. Clearance allowances to provide for vertical and horizontal movements of equipment due to lateral play, wear and spring deflection, collaborating with the Mechanical Division, AAR.

   Progress report, presented as information .... page 559

The Committee on Clearances,
A. M. Weston, *Chairman.*

AREA Bulletin 519, December 1954.

Report on Assignment 2

Clearances as Affected by Girders Projecting Above Top of Track Rails, Structures, Third Rail, Signal and Train Control Equipment

Collaborating with Signal and Electrical Sections, and with Mechanical and Operating–Transportation Divisions, AAR

C. O. Bird (chairman, subcommittee), E. S. Birkenwald, W. S. Campbell, W. T. Davis, J. E. Good, C. F. Intlekofer, M. L. Johnson, W. P. Kobat, B. F. Nauert, A. G. Neighbour, C. E. Peterson, A. J. Rankin, W. S. Ray, J. E. South, J. W. Wallenius, A. M. Weston, E. R. Word.

This is a progress report, submitted as information.

The lower portion of the clearance diagrams covering passenger and freight equipment overlaps the diagrams covering permanent structures or appurtenances on or adjacent to the tracks. Consequently, two diagrams are being developed: (1) a diagram for equipment, establishing a minimum distance of 3 in above the top of rail, and (2) a diagram for permanent track fixtures, establishing a maximum distance of 2¾ in above the top of rail, thus providing a safety space between equipment and track fixtures.

A third diagram is being developed to cover clearance lines for third-rail territory based upon the two above mentioned diagrams.

Report on Assignment 4

Compilation of the Railroad Clearance Requirements of the Various States

E. R. Word (chairman, subcommittee), W. S. Campbell, S. M. Dahl, J. W. Darby, R. L. Goss, J. G. Greenlee, W. F. Hart, A. G. Neighbour, R. C. Nissen, W. F. Pohl, A. J. Rankin, W. S. Ray, J. C. Scholtz, O. W. Stephens, R. H. Taylor, H. G. Whittet, A. M. Weston.

Your committee submits as information a tabulation of the clearance requirements of the various states brought up to date as of November 17, 1954.

LEGAL REQUIREMENTS—CLEARANCES

State	Reference	Date			Overhead clearances (tracks)	Overhead clearances – bridges, tunnels, overhead structures, engine houses	Side clearances – buildings, platforms (passenger, freight), switchstands, bridges, tunnels, engine houses, icing docks, mail cranes, water columns, water tanks, stock chutes
Alabama	None		4978	.4			
Arizona		1946			4; 4 0; 0; 20 0; 20 0; 6; 13 0	22 0; Yes; 22 0; Yes; Yes; 18 0	8 6; Yes; 8 6; 8; 4 8; 4 0; 7 3; 4 6; 8 0; 4; 3 0; 3 0; 6 0; 8 6; 8 0; Yes; 8 0; Yes; 7 8; 7 8; Exempt; 8 0; 8 6
Arkansas	None		435				
California	Gen. Order 26-D	1949	1574		4; 5; 4; 0; 0 0; 20 0; 3 0; 13 0	22 6; Yes; 22 6; Yes; 22 6; Yes; 18 0	8 6; Yes; 8 6; 8; 4 8; 4; 7 6; 4 6; 8 0; 4; 3 0; 3 0; 6 0; 8 6; 6 0; Yes; 8 0; Yes; 7 8; 8 0; 8 6
Colorado	Statutes	1950	44	34	4; 4; 5; 0	22 0; Yes; 23 0; Yes; 22 6; 18 0; Yes; 18 0	8 6; 8 6; 8; 5 0; 4 0; 5 8; 4; 3 0; 3 0; 6 0; 8 3; 8 0; 7 0; 6 8; 8 6; 8 0
Connecticut	Statutes		83				
Delaware	None						
Florida	Order No. 87	1953			13 6; 3; 19; 13 0	22 0; 17 0	8 0; 10 0; 8; 4 8; 4 0; 5 9; 4; 3 0; 3 0; 6 0; 6 0; 7 8
Georgia			62				
Idaho			2142				
Illinois	Gen. Order	1920		5 14	13 6; 13 6; 3 0; 15 0; 0; 19 0	Yes; 1 6; Except	9 0; 8; 8; 2 8; None; 8 0; Yes; 9 0
Indiana	Statutes		6857	299		22 0; 22 0; 22 0	8 0; 8 0; 8 0
Iowa	Docket A-28	1936	8906	389	4; 5 0; 13 6; 13 0; 15 0; 17 0; 17 0; 9 0	22 0; Yes; 22 0; No; 22 0	2 8; None; 8 0; 8 0; Yes; 6 3; 9 0; 7 0
Kansas	Statutes	1935	8479	370			
Kentucky	Customary		3574	14		22 0; 22 0; 22 0	
Louisiana	None		4292	87			
Maine	None		1862	0.81			
Maryland	Order No. 5038	1953	325	058	4-0; 15-0; 13-6; 18-0; 18-0; 19-0; 13-0	22-0; 22-0; 22-0; Yes; 18-0	8-6; Yes; 8; 5-1; 4 6; 8-0; 4-0; 5-7; 4 6; 8; 4; 3-0; 3-0; 6-0; 8-0; 7-8; 8-0; 8-0
Massachusetts	Statutes	1950	745	076	13 0; 13 0; 13 0; 13 0; 13 0; 17 0	22 6; Yes; 18 0	8 6; 3 0; 6 6
Michigan	Statutes	1946	7179	313	13 0; Exempt; 13 0; 13 0; Exempt; Exempt	Exempt; 22 0; 22-0; Exempt	8 0; 8-0; 8 0; 8 0; Exempt; Exempt; Exempt; Exempt
Minnesota	Statutes	1943	8371	365	10 4; 4 9; 14 0; 14 0; 14 0; 14 0; 14-0; 17 0; 17 0; 19 0; 19 0	22 0; Yes; 22 0; Yes; 22 0; No; 22-0	8 6; No; 8 6; 8 6; Yes; 8 6; Yes; 8 6; 8 6; 8 8; 8-6
Mississippi	None		3813	166			
Missouri	Gen. Order No. 24	1951	6939	303	13-6; 13 6; 13 6; 13 6; 13 6; 17 0; 17-0; 19 0; 19 0; 13 6; 13 6; 13-6; 13 0	22 0; Yes; 22 0; Yes; 22 0; Yes	8 6; Yes; 8 6; 5-1; 5 9; 3; 4-2; 4; 5; 6 6; 8 0; Yes; 8 6; Yes; 8 0; 8 6; 6 5; 8-6; 8-6; 8-6
Montana	None		5105	223			
Nebraska			5877	257			
Nevada	Case No. 59	1942	628	050	10 8; 5; 4 0; 15 0; 14 0; 20 0; 20 0; 20 0; 20 0; 11-6; 13 0	22-0; Yes; 22 0; Yes; 22 0; Yes; 18 0	8 6; Yes; 8 6; 8; 4 8; 4 0; 7 3; 4 6; 8 0; 4; 3 0; 3 0; 6 0; 8 6; 8 0; Yes; 8 0; Yes; 7 8; 7 8; Exempt; 8 0; 8 6
New Hampshire	Statutes		956	042	14 0	18 0	
New Jersey	None		2070	090			
New Mexico	Order No. 2202	1953	2598	3	14-0; 14-0; 15-0; 17-0; 17-0; 20-0; 13-0	22-0; 21 6; 23-0; 21 6; 22-6; 21 6; Yes; 17-0	8-6; Yes; 8 6; 8; 4 0; 5-9; 4; 3 0; 3-0; 6-0; 8-0; Yes; 8-0; Yes; 7-0; 8-0; 8-6; 8-0
New York	None		7664	334			
North Carolina	None		4628	202			
North Dakota	Statutes	1913	5262	230	0 6; 4 2; 13 0; 13 0; 13 0; 13 0; 13 0; 13 0; 13 0; 13-0; 13-0; 13-0; 13 0; 13-0	21 0; No; 21 0; No; 21 0; No	8 0; No; 8 0; 4 0; 8 0; 8 0; No; 8 0; No; 8 0; 8-0; 8-0; 8 0; 8 0; 8-0
Ohio	Adm. Order No. 9	1950	8435	369	15 0; 13 0; 15 0; 15 0; 18 0; 18 0	21 0; No; 21 0; No; 21 0; No	8 0; No; 8 0; 8 0; 8 0; 8 0; No; 8 0; No; 8 0; 8 0
Oklahoma	None		6008	263			
Oregon	Gen. Order No. 99	1916	3383	48	0 9; 5; 13 0; 3 0; 3 0; 13 0; 13 0; 16 0; 16 0; 19 0; 19 0; less than 13 0; less than 13-0	22 0; Yes; 22 0; Yes; 22 0; No; Exempt	8 6; No; 8 6; 12; 4 6; 4 0; 6 0; 6; 4 0; 2 6; 5 6; 8 6; 7 6; Yes; 7 6; Yes; Exempt; 6 6; 6 9
Pennsylvania	Statutes	1954	10088	44	13-6; 13-6; 15-0; 13-6; 18-0; 18-0; 19-0; 13-6	22-0; Yes; 18-0	8-6; Yes; 8; 5-1; 4-6; 8-0; 4; 3-0; 3-0; 6-0; 8-0; 8-0; 8-0; 8-0
Rhode Island	None		189	008		22-0; No	8-0; No
South Carolina	Statutes	1942	3349	46		22 0; Yes; 22 0; No; 17 0	8 6; No; 9-0; 8; 5 1; 5 8; 8 6; 8 0; Yes; 7 0; 8 6; 8 6
South Dakota	Order F. 348	1935	3988	174			
Tennessee	Statutes	1949	3503	53	14 0; 14 0; 14 0; 13 0; 14 0; 18 0; 18 0; 18 0; 18 0; 14 0; 14 0; 13 0; 13 0	22 0; Yes; 22 0; Yes; 22 0; Yes; 17 0	8 0; Yes; 8 0; 8; 4 8; 6; 4 8; 4 6 8 0; 4; 3 0; 6 6; 8 0; 8 0; Yes; 8 0; Yes; 8 0; 7-0; 6 5; 8 0; 8 0; 8 0
Texas	Statutes	1925	15865	6.92		22 0; Yes; 22 0; 22 0; Exempt	8 6; 8 6; 12; 4 6; 8 6; 6; 4 0; 2 6; 5 6; 8 6; 7 6; Yes; Exempt; Exempt; Exempt; 7 0; 6 6
Utah	Gen. Order No. 66	1953	1908	083	14-0; 14 0; 15 0; 13 0; 13 0; 17 0; 17 0; 20 0; 20 0; 11 6; 11 6	22 6; Yes; 22 6; Yes; 22 6; Yes; 18 0	8 6; Yes; 8 6; 8; 4 8; 1 9; 5 8; 4 0; 7 3; 4 6; 8 0; 4; 3 0; 3 0; 6 0; 8 6; 8 0; Yes; 8 0; Yes; 7 6; 7-8; Exempt; 8 0; 8 6
Vermont	Statutes		915	045		22 0; 22 0; 22 0	7 6; 7 6
Virginia		1952	4205	64			
Washington	Gen. Order No. 8439	1950	530	23	10 10; 15 6; 14 0; 14 0; 15 0; 14 0; 14 0; 20 0; 20 0; 20 0; 20 0; 14 0; 14 0; 13 0; 14 0	22 6; Yes; 22 6; No; 22 6; No; 18 0	8 6; No; 8 5; 8; 4 8; 4 0; 5 9; 3 0; 6 0; 8-0; 8-0; Yes; 8 0; No; 7 6; 5-9; 8-6; 8 0; 8-6; 8 6
West Virginia	Gen. Order No. 121		3763	64	15-0; 15-0; 15-0; 18-0; 13-0; 13-0		
Wisconsin	Statutes		5545	285	4 0; 14 0; 14 0; 14 0; 14-0; 14 0; 14 0; 14 0; 14 0; 14 0; 14 0; 14 0; 14 0	22 0; 22 0; No; 22 0	8 6; No; 14 6; 5 0; 6 4; over 5-0; 8 6; 8-6; No; 8 6; No; 8-6
Wyoming	None		2008	088			
Dist. of Columbia	Statutes	1954			14-0; 14-0; 15 0; 14 0; 14 0; —; 18-0; —; 19-0; —; 13-0	22-0; Yes; 22-0; Yes; 22-0; Yes; 18-0	8-6; 8; 4-8; 4-0; 5-7; 4; 3-0; 3-0; 6-0; 8-0; Yes; 8-0; Yes; 8-0
Canada	Canadian Board of Transport Commissioners and Statutes				13 0; 13 0; 14 0; 13 0; 15 0; 15 0; 18 0; 18 0; 12 0; 12-0	22 0; Yes; 22 0; Yes; 22 0	8 4½; Yes; 4 0; less than 8 4½; 8 0; Yes; 8-0; Yes

—EXPLANATORY NOTES—

Exceptions where trainmen or yardmen are required to couple or uncouple cars on bridge in performing switching service on a switching lead

Between main and first track or siding and first track if siding less than 15 0

Where used principally in loading or unloading refrigerator cars

Commission specifies clearances for structures over tracks

Now under consideration for revision

If no clearance restrictions on opposite side of track and on tracks other than main

Tell tales to be erected if clearance less than 22 0. Less than 18 0 requires approval from Dept of Pub. Utilities

Allows extension of facilities in existing clearances if conform to 1913 laws

Overhead clearances less than 21 6 must be filed with Public Service Commission

General practice for overhead crossings

Requires tell tales if clearance less than 18

Applies to covered bridges

P.S.C. Gen. Order No. 1003 Sept. 4, 1923

(14) Roundhouse and shop door only 6 6 Hor 17-6 Vert Comm Order Nov 11 1944

(15) 9-0 on curves less 400 radius

(16) Except in cities with power to regulate

Track center 0"-4" 14 0
4"-8" 14-3
8"-12" 14-6
12"-16" 14 9
Over 16" 15-0

8 or less 4 8
8 to 4 0 - 7 6

Warehouse and transfer platforms - 5-9
Over 4 0 for reefers - 8 0

—GENERAL NOTES—

Overhead clearances converted to top of rail if laws provide base of rail using 6" difference

Clearances generally for tangent track. Most laws specify increases for curved or superelevated track

Side clearances are from center line of track

(19) Overhead crossings and viaducts

(20) Sufficient clearance to provide for the safety of any employee or servant in normal operation of railroad

REVISED 12-17-51
REVISED 11-54

Report on Assignment 5

Clearance Allowances to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear, and Spring Deflection

Collaborating with the Mechanical Division, AAR

S. M. Dahl (chairman, subcommittee), C. O. Bird, B. Bristow, A. B. Chapman, R. L. Goss, J. G. Greenlee, A. R. Harris, J. D. Hudson, C. F. Intlekofer, F. Martin, R. C. Nissen, C. E. Peterson, A. D. Quackenbush, J. W. Wallenius, A. M. Weston, E. R. Word.

This report is presented as information only. It is a summary of work done and the results achieved to date on the above assignment.

The calculation of clearance requirements for passenger cars involves the following factors:

1. Width of car.
2. Overhang at ends and middle of car due to curvature.
3. Superelevation.
4. Play between wheels and rails.
5. Displacement due to swing hanger movements and lateral play and wear in truck parts.
6. Tilting of car body due to unequal spring deflection and play in side bearings.
7. Allowances for the effect of track irregularities and dynamic behavior of equipment.

This report is concerned only with factors 5, 6 and 7.

If all trains were operated at equilibrium speed, there would be no problem as far as factors 5 and 6 are concerned, and factor 7 would be of less importance. Since the opposite is nearly always the case, it was decided to attack the problem by studying the forces working on a car body when moving out of equilibrium. Under this condition, the centrifugal force is not balanced by the superelevation in the track and, as a result, a condition exists commonly referred to as "unbalanced elevation."* This value can be determined from the following formula:

$$E_u = E_r - E_a$$

where

E_u = Unbalanced elevation.
E_r = Elevation required for equilibrium.
E_a = Actual track elevation.

The unbalanced elevation may be static or dynamic and the horizontal force working on a car body at rest on a superelevated track is equal to the centrifugal force working on the car body moving on a curve at an equal unbalanced elevation. Theoretically this may be proved as follows:

The horizontal force working on a car body at rest on a superelevated track is

$$H = W \frac{E_a}{60}$$

and the unbalanced centrifugal force is

$$F_u = W \frac{E_u}{60}**$$

* For definition, see Proceedings, Vol. 54, 1953, page 836.
** For proof see Proceedings, Vol. 56, 1955, page 136 (Bulletin 516, June–July 1954, page 136).

where

W = Weight of car body.
E_a = Superelevation of track.
E_u = Unbalanced elevation.
Distance between bearing points on rail is 60 in.

When $E_u = E_a$, F_u must equal H, and the effects on the car body should be the same.

It is evident, therefore, that by measuring the lateral movements of a car at rest on a superelevated track, a measure can be obtained of the lateral movements of a car under dynamic conditions. The amount of movement will vary directly in the proportion the dynamic unbalanced elevation is to the static test elevation and may be expressed by the following formula:

$$R = L\frac{E_u}{E_s}$$

where

R = Lateral displacement of any point on a moving car with reference to perpendicular center line of truck (Fig. 2).
L = Lateral displacement as above at rest at E_s elevation.
E_u = Unbalanced elevation.
E_s = Static test elevation.

In order to test the practical value of the theoretical calculations, tests were made by the AAR under the direction of G. M. Magee, director of engineering research. A report on these tests can be found in Bulletin 516, June–July 1954, page 125 (Proceedings, Vol. 56, 1955, page 125), and will not be discussed here except to say that the results were favorable and substantially confirmed the theoretical calculations.

The steps to be taken to determine lateral displacement with reference to the center line of trucks are as follows:

1. Make static field test on car in question at one or more superelevations and make measurement as shown in Fig. 1.

2. Calculate L (Fig. 1) for each superelevation.

3. Plat L values as in Fig. 3 and draw line through the zero of coordinates and average of L values and extend line into area of plus values of unbalanced elevation and displacement.

4. Calculate unbalanced elevation E_u from the following formula:

$$E_u = E_r - E_a$$

5. Determine R from either of two methods as follows:
   a. Graphically from diagram platted under step 3. (See Fig. 3)
   b. From formula $R = L\,\frac{E_u}{E_s}$

Example:

Find R for a car whose L values are platted in Fig. 3 at a speed of 50 mph on a 4-deg curve with 4 in superelevation.

By Method a:

$$E_u = E_r - E_a$$
$$= 0.0007\, DV^2 - 4$$
$$= 0.0007 \times 4 \times (50)^2 - 4$$
$$= 7 - 4$$
$$= 3 \text{ in}$$

From Fig. 3, the value of R corresponding to 3 in unbalanced elevation is 3.4 in.

By Method b:

Assume that only one L value was determined at 6 in unbalance in static test. From Fig. 3, $L_6 = 6.8$ in.

$$R = L\frac{E_u}{E_s} = \frac{6.8 \times 3}{6} = 3.4 \text{ in}$$

Example:

Same data as above except speed is 10 mph.

By Method a:

$$E_u = 0.0007 \times 4 \times (10)^2 - 4$$
$$= 2.8 - 4$$
$$= -1.2 \text{ in}$$

The minus sign indicates that displacement is inward from equilibrium, and from Fig. 3, R is found for -1.2 in unbalanced elevation and is equal to -1.4 in.

By Method b:

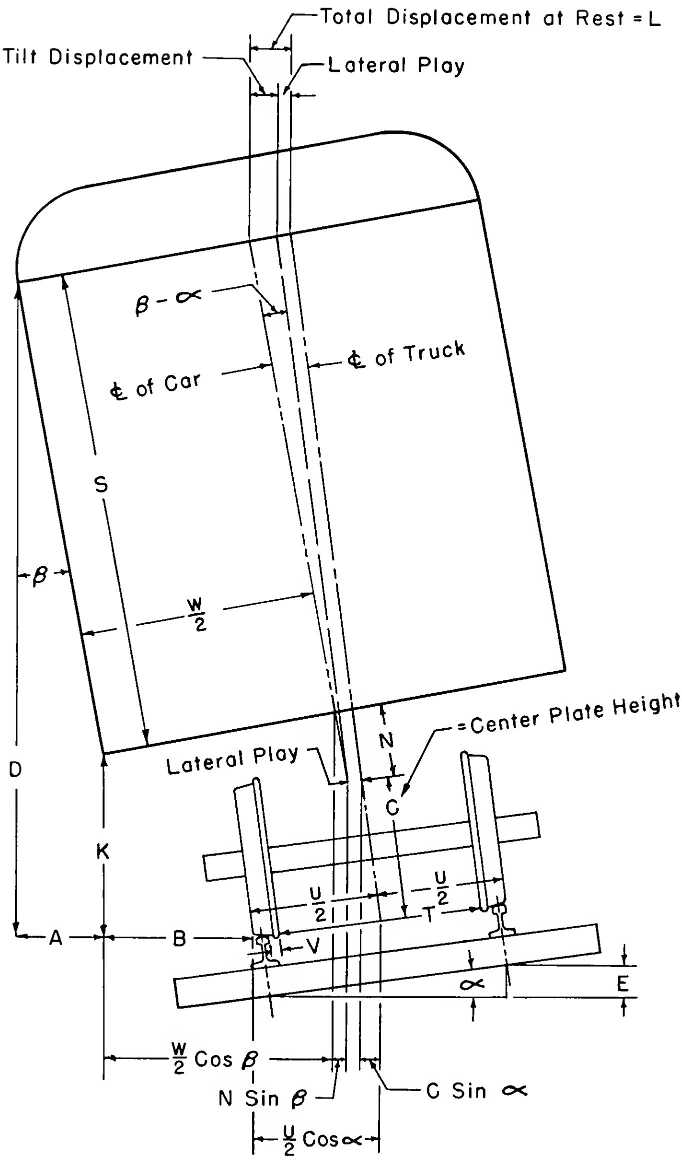
$L = 6.8$ in at 6 in unbalanced elevation

$$R = L\frac{E_u}{E_s} = \frac{6.8 \times (-1.2)}{6} = -1.36 \text{ in}$$

In the above method of calculating displacement, it is assumed that the lateral movements in truck parts due to play and wear is proportional to the unbalance. This is not exact, but the error is not great and for all practical purposes can be ignored.

The results obtained are only as good as the basic information, such as degree of curvature and superelevation. For best results, it is recommended that actual field conditions be determined. Curvature can best be checked by string lining and superelevation can be determined from actual field check. Variation of only a few minutes in curvature should not be ignored.

Since track and equipment conditions are not perfect, an allowance must be added to the calculated displacement to provide for minor track irregularities and the dynamic behavior of equipment. An analysis of charts platting the roll of passenger cars in tests conducted by the AAR discloses that the variation of roll varies substantially with the speed. This subject will be given further consideration before a report is made.



$$L = (S+N)\sin(\beta-\alpha) + \left(B + \frac{U}{2}\cos\alpha\right) - \left(\frac{W}{2}\cos\beta + N\sin\beta + C\sin\alpha\right)$$

FIG. 1 DIAGRAM SHOWING STATIC TEST MEASUREMENTS REQUIRED FOR CALCULATION OF "L"

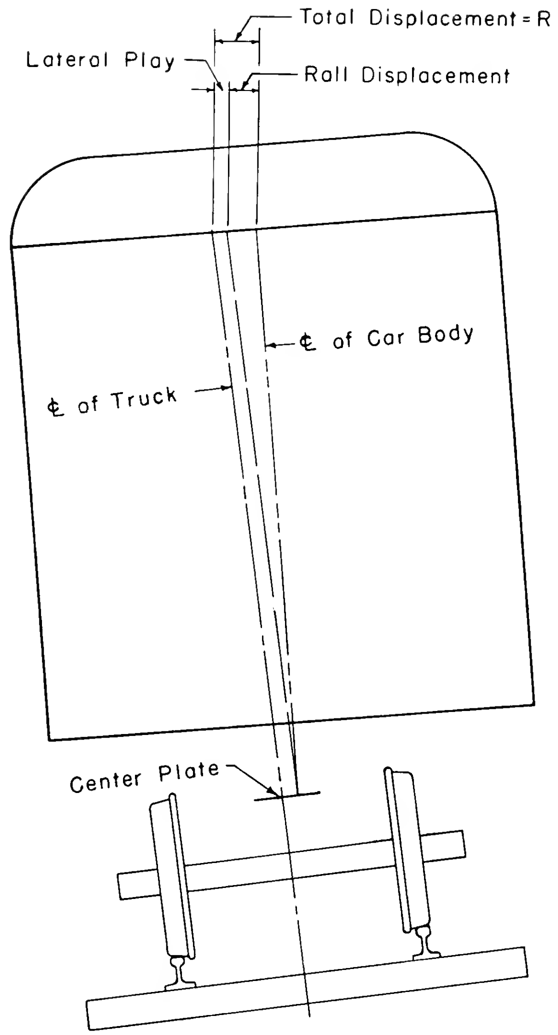


FIG. 2 DIAGRAM SHOWING DISPLACEMENT "R" OF A CAR MOVING ON A CURVE IN EXCESS OF EQUILIBRIUM SPEED

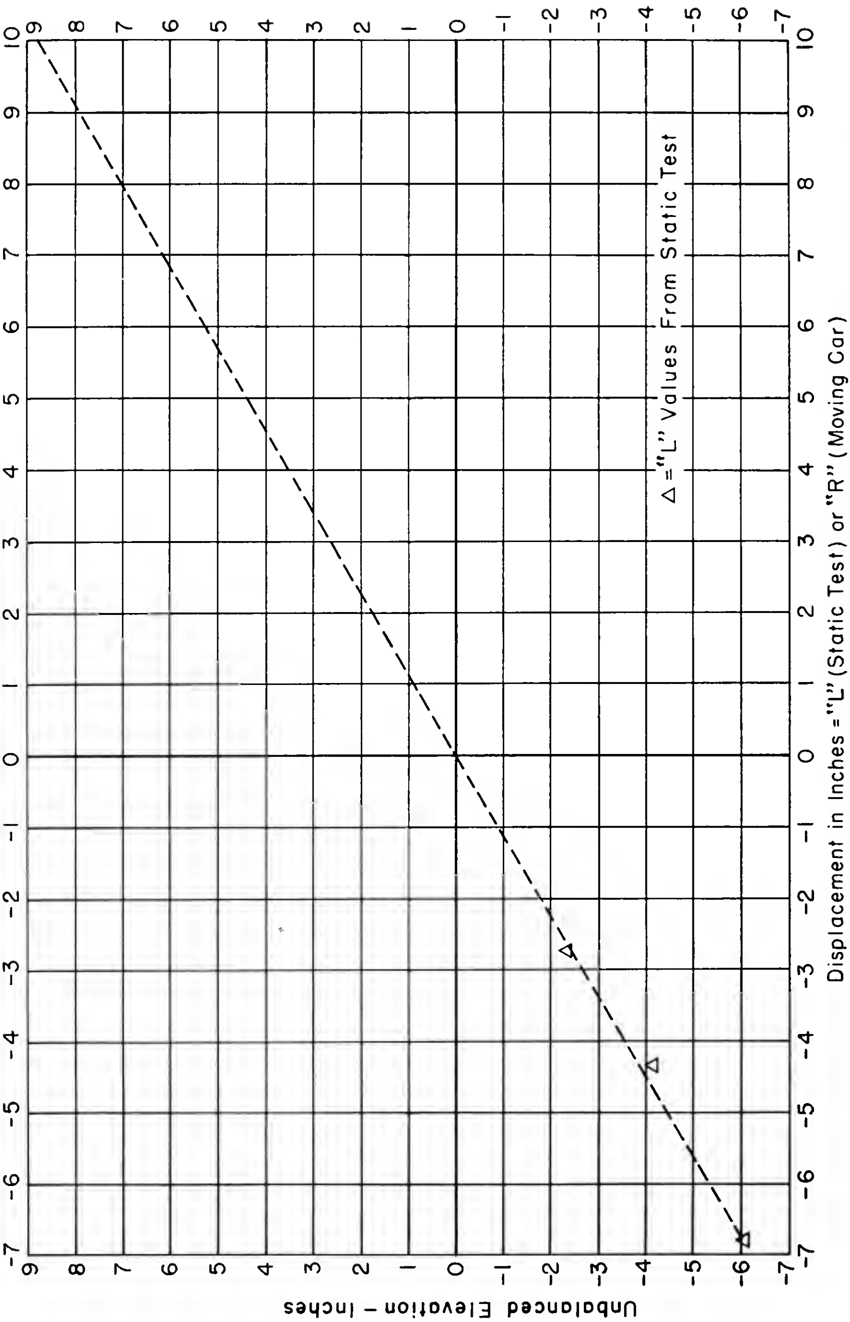


FIG. 3 DIAGRAM SHOWING RELATION BETWEEN DISPLACEMENT AND UNBALANCED ELEVATION

Report of Committee 24—Cooperative Relations with Universities

R. J. Stone, *Chairman,*
L. L. Adams
M. B. Allen
W. S. Autrey
J. B. Babcock
George Baylor
T. A. Blair
Armstrong Chinn
R. P. Davis
G. H. Echols
O. W. Eshbach
P. O. Ferris
C. G. Grove
E. M. Hastings (E)*
W. W. Hay
W. E. Heimerdinger
J. P. Hiltz, Jr.
S. R. Hursh
A. V. Johnston
G. A. Kellow
Frank Kerekes
W. S. Kerr
H. E. Kirby
T. R. Klingel
N. W. Kopp
B. B. Lewis
F. J. Lewis
H. S. Loeffler
E. E. Mayo
G. W. Miller
C. H. Mottier
W. H. Huffman, *Vice Chairman,*
R. C. Nissen
L. M. Ogilvie
W. A. Oliver
J. F. Pearce
J. E. Perry
R. B. Rice
W. T. Rice
J. A. Rust
W. C. Sadler
P. S. Settle, Jr.
H. O. Sharp
D. W. Tilman
Barton Wheelwright

Committee

(E) Member Emeritus.
* Died November 21, 1954.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Stimulate greater appreciation on the part of railway managements of
   (a) the importance of bringing into the service selected graduates of colleges and universities, and
   (b) the necessity for providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

   Progress report, presented as information .... page 566

2. Stimulate among college and university students a greater interest in the science of transportation and its importance in the national economic structure, by cooperating with and contributing to the activities of student organizations in colleges and universities.

   Progress report, presented as information .... page 568

3. The cooperative system of education, including summer employment in railway service.

   Progress report, presented as information .... page 572

4. Conduct a study looking to the publication of a booklet, or booklets, for distribution to educational groups, particularly high schools and undergraduates in colleges, designed to stimulate interest in the opportunities afforded in a railroad engineering career.

   Progress report, submitted with committee's recommendation that the Board of Direction give consideration to the development of this material into an attractive brochure for distribution to undergraduates in colleges and others interested, either as an AREA project or in conjunction with the AAR .... page 575

A

Special report of C. G. Grove on annual meeting of the American Society for Engineering Education at the University of Illinois, June 14–18, 1954 ..... page 586

The Committee on Cooperative Relations With Universities,
R. J. Stone, *Chairman.*

AREA Bulletin 520, January 1955.

Report on Assignment 1

Stimulate Greater Appreciation on the Part of Railway Management of:

a) the importance of bringing into the service selected graduates of colleges and universities, and

b) the necessity for providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

D. W. Tilman (chairman, subcommittee), M. B. Allen, G. H. Echols, J. P. Hiltz, Jr., W. H. Huffman, N. W. Kopp, F. J. Lewis, C. H. Mottier, R. B. Rice, W. T. Rice, P. S. Settle, Jr.

This is a progress report, submitted as information.

As the result of the third of a series of executive research surveys begun in 1951 by the Professional Engineers Conference Board For Industry with the cooperation of the National Society of Professional Engineers, a report has been issued entitled "How To Attract and Hold Engineering Talent." This report reflects the experiences of more than 200 companies and the attitude of 1400 individual engineers who are employed in industry.

The topics under study were selected by some 100 major industrial employers of engineers. These employers were asked to select from a list of management problems those subjects on which they would like to have data derived from the experiences of many companies and from engineers employed by these companies.

The report is rather voluminous, and the following is merely the summary of the report, which is presented for the benefit of railway managements and AREA members generally:*

> The solution of the problem of attracting and holding engineering talent—of keeping engineers happy as employees—lies not alone in industry, but must be sought first in the schools whence come our annual crop of fledgling engineers.
>
> It is apparent from the testimony of both industrial executives and engineers employed in industry that our engineering schools are not producing the raw material that industry needs.

Curriculum Too Narrow

> Both groups believe the schools should broaden the engineering curriculum to include more non-engineering studies, particularly in the fields of English, the humanities, social studies and business administration.

* Complete copies of the report can be secured from: Mr. Paul H. Robbins, P. E., Secretary, Professional Engineers Conference Board for Industry, Inc., 1121 15th Street, Washington 5, D. C. Price per copy: Single copies $1.00; Non-Members $2.00.

To this end it is strongly recommended that leaders of industry maintain closer liaison with the schools, assisting administrators and faculty in the preparation of the courses of study which will produce the kind of graduates industry needs.

It is also proposed that industry offer its cooperation to the schools in setting up short courses designed to bring to the students a more nearly accurate picture of the job situations they will face after graduation, and to provide instructors from industry for such courses.

Current campus recruiting practices, which have been pushed to extreme lengths because of excessive competition due to the widening gap between supply of and demand for new engineers, are sorely in need of a thorough overhauling.

The prevalent practices of running up the young engineer's starting salary by competitive bidding, and of over-selling the company in an effort to "lure" recruits with romantic but not always accurate pictures of the opportunities which await the job candidate, often, in the long run, defeat their own ends. Too frequently the new recruit meets disillusionment and consequent dissatisfaction.

Vacation Programs

More extensive vacation work programs for students are recommended both as a means of acquainting the job candidate with actual conditions in industry and as a device to enable the prospective employer first to evaluate his candidates, and secondly, to develop and maintain contact with them long before they are thrown on the labor market.

If these recommendations are carried out, it is thought, the engineering graduate will come to the job with a background of knowledge which will more nearly fit him for the tasks ahead and he will, in consequence, be a happier and better adjusted employee, ready and willing to tackle routine and relatively unimportant assignments while he is preparing himself for positions of greater responsibility.

Some modifications in the average employer's attitude toward his engineers also seems indicated in order to bring about a situation in which the latter can work contentedly and efficiently in an employee capacity.

A separation of personnel functions as regards professional and nonprofessional employees seems indicated, with a greater degree of recognition of the engineer's professional status.

Registration Desirable

The engineer will be happier if he is given the widest variety of work assignments consistent with the company's operating procedure. He also should be encouraged to register and to participate actively not only in professional organizations but also in such activities as writing, public speaking and community affairs.

In most companies, it appears that there is a necessity for clearing out existing channels of communication between management and engineers and, in many cases, the creation of new and better channels. Few engineers seem to have been kept sufficiently informed of their companies' business objectives—or even of their own personal progress in the firm.

Like most other workers, the engineer is interested primarily in security and opportunity for advancement, and all programs linked to those objectives will aid in keeping him contented. Especially desirable are comprehensive training programs, designed to fit the engineer for more responsible positions.

Two out of three engineers employed in industry do not want membership in labor unions, but many feel they would benefit by belonging to a non-bargaining, interplant organization which would serve as a vehicle of expression and a means of communication. That so large a percentage favor unions, however, points to the necessity for immediate steps on the part of both industry and the professional societies.

Other Devices

Some of the other means used by companies participating in the survey to attract and hold their engineers follow:

- Payment of tuition, in whole or in part, for advanced study.
- Engineering scholarships for employees' children.
- Profit-sharing and stock bonus plans.
- A policy of promotion from within the company.
- Payment of initiation fees and dues in professional societies.
- Merit rating systems or other means of keeping them currently informed of their personal progress within the company.

Report on Assignment 2

Stimulate Among College and University Students a Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure

By Cooperating with and Contributing to the Activities of Student Organizations in Colleges and Universities

R. P. Davis (chairman, subcommittee), L. L. Adams, W. S. Autrey, T. A. Blair, W. H. Huffman, E. E. Mayo, G. W. Miller, J. E. Perry, J. A. Rust, Barton Wheelwright.

This is a progress report, submitted as information.

Under date of October 4, 1954, your committee sent out letters to all members of Committee 24 requesting information on their activities during the current year which, directly or indirectly, contributed to the activities of student organizations in colleges and universities. The following summarizes some of these activities.

The following quoted material comes from a letter from George H. Echols, chief engineer, Southern Railway System:

"At the National ASCE Convention, which was held in Atlanta, Ga., on February 20, 1954, the Southern Railway entertained various student representatives of Junior Chapters from many colleges who were in attendance at the Convention. The entertainment consisted of a tour of Atlanta, with emphasis on some of our railroad facilities, . . .

"The tour stopped at our Atlanta shops and a barbecue was served, followed by a program of musical entertainment in which the various student groups participated by singing their own college songs. After lunch, the tour was resumed through the downtown section of Atlanta and disbanded in the afternoon at the Biltmore Hotel, convention headquarters.

"I recently had the pleasure of talking to the Georgia Tech. Junior Chapter of ASCE on the subject of 'Modern Mechanization and Modern Methods of Automatic

Yard Construction and Operation'. Also, I recently talked to the Junior Chapter of ASCE at Catholic University here in Washington, on the same subject as that used at Georgia Tech.

"As you know, the Southern Railway is very much interested in obtaining young engineering graduates to place in our student training program, which we have had in effect since 1914. Practically all of our officers, including our president, operating vice president, and many others down to the position of track supervisor, are graduates of our student training system.

"We are especially interested in the activities of Committee 24 as we feel that our industry should advertise more to the younger generation than we have in the past, as we find that in recent years fewer young men turn to railroading as a career."

Professor W. W. Hay of the University of Illinois reported that on December 9, 1953, Allen Sams, office engineer, Illinois Central Railroad, spoke to their senior civil engineers on the subject of "Operation and Modernization of Markham Yard". On March 3, 1954, C. H. Mottier, vice president and chief engineer of the same railroad addressed the students on the "Reconstruction of the Illinois Central Railroad's Cairo Bridge". On October 6, 1954, C. F. Nelson, industrial agent, Rock Island Lines, spoke before the same group on the subject, "New Jobs for Civil Engineers on the Railroads".

According to Professor Hay, his classes in railroad construction and maintenance and railway signaling made field trips on the Illinois Central to observe a mechanized rail laying gang and to visit a train dispatcher's office and an interlocking plant.

J. P. Hiltz, Jr., chief engineer maintenance of way–system, New York Central System, reported having private conferences with a number of graduate students during the establishment of the Central's Junior Engineer set-up, which at the present time consists of 16 men assigned to various places and duties on their system. These men are being trained on a very definite program basis on the premises that they will eventually be promoted to the status of officers, depending on aptitude and ability.

On May 31, 1954, Clark Hungerford, president, St. Louis–San Francisco Railway Company, spoke before the graduating class of the School of Mines and Metallurgy of the University of Missouri. Much of his address represents the typical thinking of the railroad engineer with heavy administrative responsibilities. The following excerpts from this address will be of interest to the readers of this report:

"In 60 years, the number of engineers per 100,000 industrial workers has more than quadrupled. This trend may be expected to continue, because present and prospective developments in power, in electronics, and in other technical fields require increasing scientific and engineering direction.

"But aside from the need for technically competent men there is the demand for men who have been trained to accept responsibility for carrying out work, and who have the capabilities of supervising other men. The fact is that men trained as engineers are greatly in demand for positions of industrial and business management. About 40 percent of the top positions in this country's largest industries are held by men who have had engineering training. All of this is a measurement of the opportunities of your profession.

"Engineering takes in a great many things. It's building; it's planning; it's analyzing; it's testing; it's correlating cause and effect; it's directing the work of others. Its function in the social order can be traced back beyond the pyramids. In a broad sense, engineering is the art of applying the materials and forces of nature to the benefit and convenience of men . . . and doing it in the most economical manner. It is a profession closely allied with pure science.

"Today your profession is highly specialized. At the same time each specialized field offers broadened avenues for the application of engineering principles. One of the oldest fields of engineering is in transportation. Two hundred and twenty-five thousand miles of railroads in this country are a monument to engineering achievement. They also represent a fertile field for future accomplishments. After more than 30 years in railroading I would be the last to suggest that we have even approached the last frontier. The job of providing low-cost mass transportation in a period of high costs and high taxes is a continuing challenge. Mindful of the need for technically trained men, we make a determined effort to attract engineering graduates, and to aid them in their advancement. In the case of our own railroad we have a training program for the purpose of developing supervisory officers in the maintenance of way and operating departments. The course gives the trainee a good coverage of railway experience in the shortest time possible, in our case 2½ years. From then on his promotion and development is dependent on his willingness and upon his ability."

On November 30, 1954, W. H. Huffman, assistant engineer of maintenance, Chicago and North Western System, made an address before the engineering students of the South Dakota State College at Brookings, S. D.

W. S. Kerr, now vice president and business manager, Northwestern University, and formerly executive assistant, Burlington Lines, lists the following appearances at Northwestern University: June 13, 1954, a talk at the Traffic Institute Pre-Graduation Dinner; June 16, 1954, an address before the School of Mortgage Banking, entitled "Some Current Problems in Business Management; and October 5–6th, 1954, talks at new student convocations.

From Professor B. B. Lewis of Purdue University comes the information that Professor K. B. Woods, Head of the Civil Engineering Department at Purdue, gave an illustrated lecture on the construction of the new railroad in Labrador before the Purdue University Student Chapter of the ASCE on December 15, 1953.

C. H. Mottier, mentioned previously as a speaker at the University of Illinois, reported on the annual inspection trip of the Purdue senior civil engineering class at Markham Yard, which usually comes in October.

In an interesting letter from Division Engineer N. W. Kopp of the Illinois Central Railroad, he reported that on January 12, 1954, a group of local officers of the Illinois Central Railroad, consisting of J. R. MacLeod, freight traffic manager; F. K. Stanford, superintendent; J. F. Wilkinson, supervisor of track; W. R. Jones, assistant freight traffic manager; James E. Gardner, general freight agent; E. J. Meade, general passenger agent, and himself, met with 250 students and department heads at the University of Mississippi, under the direction of Dr. William T. Hicks, chairman of the School of Commerce and Business Administration.

Quoting Mr. Kopp: "At this meeting we related the story of the Illinois Central, with emphasis on economics and business activities in Mississippi. Following this general meeting, the Illinois Central group was assigned to group discussion with advanced classes in market research, industrial relations, principles of industrial management, foreign trade, transportation and engineering. Each of these meetings consisted of question and answer sessions."

On April 27, 1954, the same group and V. T. Johnston, executive general agent of the Illinois Central, attended a business outlook seminar with 18 faculty members of the University of Mississippi in attendance.

Professor Fred J. Lewis of Vanderbilt University reports meeting with many high school groups during the early spring in connection with their high school visitation program. Quoting from his letter: "Perhaps the two best occasions that were offered to me during last year were the vocational program given at Tennessee Polytechnic Institute in Cookeville, where there were something like 2000 high school students present, and a similar program at Clarksville, where there were almost as many juniors and seniors congregated."

Dr. Robert B. Rice, Head of the Department of Diesel and Internal Combustion Engines at North Carolina State College, reported a number of activities, including a Diesel Symposium, which was attended by the engineering staffs of several railroads and by engineering students from Duke University and from his own school. Various aspects of railroading were discussed, with special emphasis on the diesel locomotive and its problems. Other activities included an address before the engineering faculty and students at Duke University, and the arrangement of inspection trips for students.

W. T. Rice, general superintendent, Richmond, Fredericksburg and Potomac Railroad, participated in a program involving students studying railroad maintenance and operation at the Army Transportation School at Fort Eustis, Va. These young officers were being given a brief familiarization course in railroading prior to being assigned to various railroads in the country to observe the supervisor in his day-to-day work.

W. C. Sadler, professor of Civil Engineering at the University of Michigan, lists trips by his students to points of interest, including one to the diesel shops of the Ann Arbor Railroad at Owosso, Mich., with A. T. Scherer, master mechanic, conducting the trip; one to inspect the terminal facilities of the New York Central Railroad at Detroit, Mich., conducted by W. H. Shearer, superintendent at Detroit; and one to the Pennsylvania Railroad terminal at Toledo. Another activity consisted of bringing a group of students to the AREA convention in Chicago

Professor H. O. Sharp, head, Division of Geodesy and Transportation Engineering at Rensselaer Polytechnic Institute, reported continued interest on the part of students in railroad engineering courses at Rensselaer. Over the years this institution has established an enviable reputation for supplying the railroads with outstanding men.

D. W. Tilman, special engineer, Baltimore & Ohio Railroad Company, visited 8 universities and talked to about 75 seniors in the interest of their Technical Graduate Training Course.

A seminar on "Railroad Management—The Next Generation" was held on February 10 and 11, 1954, at the University of Michigan, in which three members of Committee 24 participated. S. R. Hursh, chief engineer, Pennsylvania Railroad, presented a railroad viewpoint on the subject of methods by which railroads can effectively recruit and select potential managers and leaders for their executive ranks.

Mr. Hursh emphasized the fact that effective recruiting depends largely on having something attractive to offer, such as (1) a good training program, and (2) salaries sufficient to provide a good standard of living. He cited the Pennsylvania Railroad as having had a training program for 60 years for engineering graduates. From 1948 to 1953 the Pennsylvania hired a total of 203 men from 54 colleges. As of December 31, 1953, there were 725 engineering graduates in their total organization.

An academic viewpoint on this subject was presented by Professor O. W. Eshbach of the Northwestern Technological Institute. He stressed the importance of proper recruiting methods, such as adequate financing, personal contacts, advertising in school journals, and going to those schools where the talent is, regardless of whether the school is accredited or not.

In discussing another subject at this seminar, namely, what should the railroads do to train and develop their next generation of executives, C. H. Mottier, Illinois Central, made the following recommendations: (1) Select best possible recruits, whether university graduates or otherwise; (2) train the recruits; (3) put square pegs in square holes; (4) do not close the door to the non-college man; (5) unionism is a real threat (concentrate on making young supervisors feel part of management); (6) human qualities are more important (70 percent) than technical education (30 percent); (7) it is important for future executives to work with their hands, in the gangs, to get the feeling of the rank-and-file; (8) railroads should promote within their ranks; and (9) bring various executives, including juniors, into the monthly Board of Directors meeting, as the I.C. does.

Report on Assignment 3

The Cooperative System of Education, Including Summer Employment in Railway Service

O. W. Eshbach (chairman, subcommittee), W. H. Huffman, W. S. Kerr, J. B. Babcock, Armstrong Chinn, P. O. Ferris, C. G. Grove, A. V. Johnston, T. R. Klingel, R. C. Nissen, L. M. Ogilvie, J. F. Pearce, E. M. Hastings.

In past years the committee has kept the Association advised of the developments in cooperative engineering education and has reported periodically on studies relating to railroad company participation in these programs and vacation employment of graduates. More recently, when technical education, and particularly cooperative education, was threatened by emergency provisions for military preparedness, it was felt desirable to keep the Association informed of impending legislation and its possible effect upon the current and long-term supply of engineering talent. This involved contact with and participation in the studies of a number of groups likewise concerned. All of these groups were handicapped by the lack of factual information upon which to judge consequences.

Inasmuch as constructive relationships between the railroads and the universities involve an understanding of each other's problems, your committee has made available to its members the most comprehensive report resulting from the many postwar studies—"America's Resources of Specialized Talent." The report under this title was published by Harper & Brothers in September 1954. It was prepared by Dael Wolfle, director of the study made by the Commission on Human Resources and Advanced Training, which, in turn, was organized by the Conference Board of Associated Research Councils and financially supported by the Rockefeller Foundation. The work was carried on in the office of Scientific Personnel of the National Research Council.

The purpose of this report is to call to the attention of railway officers the availability of the information and to summarize briefly some observations related to the nature and supply of specialized talent.

In brief, the report discusses in separate chapters the importance of educated manpower as a national resource; classifies the major fields of specialization; traces the trends in college graduations in the several classifications in five-year periods over the last half century; gives the present distribution of graduates in occupations; discusses the factors affecting supply and demand and the potential supply; analyzes the characteristics of the students entering the several fields of specialization; and discusses the utilization and improvement in utilization of the potential supply.

In considering current and future leadership problems of the nation, the commission, upon being organized by the American Council of Learned Societies, American Council on Education, National Research Council and Social Science Research Council, directed attention to three interrelated problems.

First, what is the present supply of the many trained specialists? What are their characteristics? How rapidly have they been growing and how efficiently are they being used?

Second, what are the present and future demands relative to the supply? Where need exceeds demand, how can more students be persuaded to remain in school to acquire the necessary training to qualify?

Third, what is the potential supply? How many students who possess the potentialities are lost in the educational process? Why are they lost?

In the appendices of the report are many statistical tables for the information of those who wish to analyze further the implications of the facts. The nature of the conclusions will be characterized here by a discussion of engineering, since this is the concern of your committee.

TABLE 1

	Estimated Thousands With Degrees in Specialized Fields Living in 1953	*Thousands Employed at Professional Level in 1953*	*Thousands of College Graduates Employed*	*Percent With Degrees*	*Percent Men*	*No. Ph. D's. in 1953*
Engineers	529	633	361	57	98.5	3,750
Chemists	176	84	58	69	91	15,500
Physical scientists	168	56	41	73	76	8,250
Earth scientists	60	45	30	67	94	2,700
Biological scientists	232	52	46	88	75	13,800
Physicians	194	185	185	100	93	----------
Dentists	75	84	84	100	96	----------
Nurses	38	340	87	26	2	----------
Business and commerce	580	1,372	741	54	85	450
Education	983	1,141	725	64	28	12,650
Lawyers	280	202	177	88	96	490
Ministers	----------	168	101	60	95	----------
Psychologists	95	22	20	92	64	4,450
Social scientists	578	47	35	74	74	13,450
Humanities and arts	839	114	82	72	51	15,350
Social workers	----------	77	58	75	31	----------

The present supply of special talent in America is partly shown in Table 1. In general, it represents a group of about 5 million people out of a population of 160 million, and about 8 percent of the 60 million employed. Each of these fields is limited to those who, by further education or training, have acquired certain specialized knowledge and skill. Not all, but a major part of the comparative development of our civilization has been due to their efforts or achievements. Likewise, the dominant role of education is evidenced by the varying percentages of college-trained personnel. Of particular interest are the first seven classifications representing one quarter of the group, half of whom are engineers. Basically, their efforts depend upon a knowledge of physical and biological sciences. In growth over the last half century they have, with the exception of medicine and dentistry, exceeded many times the rate of growth of our population. In view of this it is difficult to understand the decreasing percentage of high school students who elect to study the sciences in preparation for college.

Most fields have at times experienced shortages. This has been particularly true of engineers in the postwar period. It is gratifying to note that the low point of supply has been passed and that in the next five years a better balance between supply and demand, about 30,000 per year, may be anticipated; even this may be short of current needs. Longer term predictions are more speculative. For example, Table 2 shows the predictions of college graduations up to 1970.

TABLE 2—PROJECTED HIGH SCHOOL AND COLLEGE GRADUATES

Year	*High School Graduates*	*College Graduates*
1954	1,274,000	286,000
1955	1,327,000	272,000
1956	1,396,000	283,000
1957	1,400,000	288,000
1958	1,475,000	292,000
1959	1,582,000	307,000
1960	1,777,000	326,000
1965	2,446,000	454,000
1970	--------------	591,000

It would be unrealistic to expect the number of engineering graduates to increase at a faster rate than all college graduates. For more than 12 percent of all graduates to be engineers is high in the light of past experience. Only under the artificial stimulation of war activities has this been exceeded. Also, the competition in interests of high school students in relation to all other fields of specialization shows little promise of material change. A greater potential change which could affect the supply of all specialists lies in the salvaging of lost potentialities in public school education. For example, in the 18-year age group there are over 2 million people, only 60 percent of whom are graduated from high school, approximately 24 percent go to college, and 12 percent will be graduated from college. The last mentioned percentage may increase to 18 percent by 1970. The commission's report analyzes the intellectual potential of this last group and the contributing causes. Corrective measures will have to await the enlightenment of parents, teachers and the population as a whole.

It would be strategically advisable to concentrate on higher quality and better utilization of special talent and greater effort in the training of less privileged employees.

In comparison with all college graduates, the analysis of the qualifications of engineers is quite favorable. In general, the group comes from the upper half of high school graduates and rates slightly superior to the average college graduate in intelligence. This is particularly true of all in the science field. With reference to social–economic heritage, they likewise compare favorably. In this connection it is interesting to note that the upper half of all college graduates compares in intellectual potential to the upper 15 percent of the population of the country. The serious losses occur in the large percentage of the superior individuals who for lack of motivation, social–economic background, finances, and adequate guidance fail to continue their education, or neglect to prepare adequately for continued study in college should this opportunity later materialize.

The American democratic system of compulsory education for everyone is unique among the nations. Its results are most frequently criticized for failure to advance the potentially superior to the same degree as is done in countries where class privilege prevails. Who goes to college in America may be determined more than is appreciated by who wants to go. This does not correlate too well with who should go. The major screening factors are the possession of adequate ability, satisfactory previous school work, money to pay expenses, and desire. The last, influenced by and influencing the others, is too frequently the earliest determinant. Judgments arising from social–economic background, lack of information, and stimulating intellectual environment, prematurely determine the careers of many with superior potentialities.

Our industrial and business world, together with the professions, can do much to develop better understanding at the early high school level. Such activities as are exemplified by this committee in preparing information on the railroad industry, supporting cooperative education, and summer employment of students, are important contributions to more effective guidance and motivation of youth.

Report on Assignment 4

Conduct a Study Looking to the Publication of a Booklet, or Booklets, for Distribution to Educational Groups, Particularly High Schools and Undergraduates in Colleges, Designed to Stimulate Interest in the Opportunities Afforded in a Railroad Engineering Career

Collaborating with the Mechanical Division, the Electrical Section, the Signal Section, and the Communications Section, AAR

G. A. Kellow (chairman, subcommittee), George Baylor, W. H. Huffman, W. W. Hay, W. E. Heimerdinger, S. R. Hursh, Frank Kerekes, H. E. Kirby, B. B. Lewis, H. S. Loeffler, W. A. Oliver, W. C. Sadler, H. O. Sharp, D. W. Tilman.

This is a progress report, submitted as information.

In last year's progress report the committee advised that it would undertake to develop a brochure intended for college undergraduate level, designed to stimulate interest in the opportunities afforded in a railroad engineering career. Accordingly, your committee has developed text material for such a brochure, which is presented herewith (see next page), and has collected photographs to illustrate suitably such a brochure.

The committee recommends that the Board of Direction give consideration to the development of this material into an attractive brochure for distribution to undergraduates in colleges and others interested, either as an AREA project or in conjunction with the AAR.

THE RAILROAD FIELD

A Challenge and Opportunity

What industry should I select as offering a happy and prosperous future?

What field of engineering offers a variety of problems to which I will be able to apply the technical knowledge I am acquiring?

What industry offers the promise of stability, security, and possibilities for advancement?

If you are an ambitious, aggressive, normal engineering student, looking for a CHALLENGE AND OPPORTUNITY, the answer to these questions may well be "THE RAILROAD INDUSTRY".

The railroads form one of the largest and most important industries in the country. The Class 1 roads (those with annual operating revenues over $1,000,000) have a total investment in road and equipment in excess of $32 billion; they employ more than 1,000,000 people; they spend annually nearly $2 billion for materials and supplies.

What part do engineers play in this railroad industry?

Back of all railroad operations is a large group of technical men from practically every branch of engineering. To these men, the railroads offer an interesting and challenging career, with exceptional opportunities for advancement both in their various engineering organizations and in other supervisory positions. Such men enjoy their work, are respected by their fellow workers, enjoy prestige in their communities, and are substantially rewarded for their efforts.

It is the responsibility of engineers to install and maintain all of the fixed properties and equipment of the railroads that make up their $32 billion investment.

The activities of a large percentage of the 1,000,000 railroad employees are directly or indirectly supervised by engineers.

Engineers assume most of the responsibility for the $2 billion annual supply bill of the railroads, either through direct use of supplies and materials or the control of quality and quantity.

Many engineers have been called on to fill high executive positions in all branches of railroading, including operations, traffic, accounting, and executive. Many railroad presidents have had engineering training and experience, and practically every major railroad in the country has men with such a background in top executive positions.

for Young Engineers

In short, the railroad industry offers the young engineer the challenge of a wide variety of difficult, interesting and complex engineering problems to analyze and solve, with the opportunity to advance in accordance with his ambitions and capabilities.

Fields in Which an Engineer May Participate in a Railroad Career

The railroad field offers many avenues of activities for the graduate engineer, suited to his preference, aptitudes and specialized training. These may be found in the Engineering, Maintenance of Way, Signal, Communications, Mechanical or Electrical Departments, in Research, or in any one of a number of other lines of railroad work.

Engineering and Maintenance of Way Departments

These departments on each railroad are responsible for the roadbed, track, bridges, buildings and allied structures, and their work is basic to the operating activities of every railroad. In them develop daily problems of every nature in the field of Civil, Mechanical, Architectural, Electrical and Chemical Engineering.

Roadway and Track

The roadbed and track are the foundation or substructure upon which all train operation is based. Railroads must build and maintain this foundation in every conceivable location—over prairies, across and through mountains, over swamps, and spanning rivers and lakes. The engineering problems involved are numerous and varied.

The Engineering and Maintenance of Way Departments of railroads today are engaged primarily in improving and maintaining existing roadbeds and tracks. In many locations cuts and fills must be stabilized, requiring surveys and studies as to best procedures. Studies and surveys are also necessary to determine the economics of line relocation to permit curve or grade reductions, or to eliminate territories requiring excessive maintenance.

The main-line track structure, including rail and fastenings, ties and ballast, must be constructed and maintained to carry high-speed passenger and freight trains safely, with maximum passenger comfort and minimum damage to lading. The railroads usually employ two groups of forces to carry out this work—one to handle ordinary maintenance, and the other to carry out new or rebuilding work. A railroad's engineering staff is responsible for programming, supervising, and inspecting the work of all these forces. Time studies are necessary to determine how labor-saving machinery and mass production methods can speed up work, improve its quality, or reduce costs. Engineers on many railroads have designed entirely new machines and completely reorganized methods to minimize hand labor.

Those in the Engineering and Maintenance of Way Departments assist in making surveys, preparing plans and supervising the construction of large new train yards for modern hump and retarder switching of cars, or the rebuilding and modernizing of existing yards to meet changing conditions. New industrial activities require extensive trackage to serve manufacturing plants. Coal and ore docks require tracks for handling materials in large quantities and under all conditions.

Bridges

An equally important responsibility of the Engineering and Maintenance of Way Departments is the design, construction and maintenance of all bridges, buildings and other structures essential to railroad operations. These structures must be engineered to provide safety to personnel and equipment, and to meet the purposes and needs of the railroad satisfactorily and economically.

Bridges and culverts of every type are used by railroads. Thus, all phases of bridge work, from the preliminary survey to determine the proper size, type and location of structures, through design, construction and inspection are the responsibility of the engineer. Sub-soil studies are needed to design substructures properly. Analyses are required to select materials and methods which will provide economical installation and reduced maintenance costs, and at the same time safely perform the service intended. In some instances simple pile and timber trestles may be required; in others long multiple through truss spans will be needed.

Existing bridge structures must be maintained in good condition. Field inspections are needed to determine what repairs may be required. The work of repair crews must be programmed, materials and equipment must be assembled, and the work supervised and inspected. New methods and labor-saving machines must be developed constantly to provide practical and economical methods of carrying out this work.

Buildings

The problems of the design and construction of new buildings of all types for many purposes are handled by the Engineering and Maintenance of Way Departments. New and modernized passenger stations are but one of the many responsibilities of the building engineer.

For properly maintaining locomotives, modern locomotive shop buildings must be provided.

Passenger and freight car shops must be designed to handle all types of construction and repair to all classes of cars, while other shop facilities are needed for rebuilding and modernizing existing rolling stock.

Storehouse facilities are required at many locations where thousands of kinds of materials, parts and supplies must be readily available daily.

Warehouses and freight-handling facilities must be provided in railway terminals to handle large volumes of less-than-carload freight with power equipment, including tractors and trailers, fork-lift trucks, conveyors, and other modern material-handling devices.

Office and welfare facilities are needed at key points to house personnel engaged in railroad activities.

Many other types of on-line and terminal structures, such as locomotive fueling, watering, sanding and cleaning facilities, and car loaders and unloaders, are required to keep the railroads operating.

The technical staff of a railroad must design and supervise the construction of all these facilities. Equally important, they must plan and carry out their maintenance.

Signal Department

The Signal Departments of the railroads have the responsibility of providing and maintaining fool-proof systems of signaling capable of controlling the movements of a large number of trains at high speeds. These systems include Centralized Traffic Control (CTC), wherein both signal lights and power switch machines over several hundred miles of busy tracks are controlled remotely by a single operator from a single panel.

Electrical engineers in the Signal Departments are called upon to assist in the design and installation of interlockings to control the movements of trains where lines of railroads meet or cross, and at automatic hump retarder yards, where one or more operators may, by merely pressing buttons or turning desk levers, line up switches for the movements of cars into any one or more of many classification tracks.

They also have jurisdiction over the design, construction, maintenance and operation of automatic train control systems, where the actual control of a train improperly operated may automatically be taken away from the locomotive engineer and controlled by signal indication; and all highway–railway grade crossing gates and signals.

It is the constant responsibility of the signal force to make operational studies to develop the economics of new and improved signal systems.

Communications Department

The communications system is the nerve network of any railroad. No railroad can function properly without dependable communications service. Electrical engineers associated with the technical staff of the Communications Department are responsible for designing communication facilities to provide such service; for developing maintenance methods to keep these facilities in operation continuously under all conditions; and for constantly improving existing layouts by adopting modern improvements in equipment and methods. Railroad communication facilities include:

Voice and message circuits to handle orders for the movements of trains, and other circuits to provide officers and supervisors the means to keep in constant contact with all activities.

Teletype networks to handle messages between departments and to furnish traffic representatives and shippers with information on the movement of commodities.

Punch card systems in larger yards in conjunction with Teletype tape transmission, to give advance information of train movements.

Radio in train operation for communication between the head end and rear end of trains, between trains and the dispatchers, and between trains themselves.

Radio in terminal operations to improve the handling of cars in train yards and enroute to industries, and thus provide better control of the activities of switch engines handling this work.

Closed-circuit television for various yard operations.

Intercom systems in yards, freight houses and offices, involving paging and talk-back speakers.

Similar equipment in train make-up and break-up yards to permit forces to coordinate their activities for improved handling of trains.

Mechanical Department

The Mechanical Department of the railroads offers a special challenge to interested, aggressive, and ambitious mechanical and electrical engineers. This department has responsibility for the design, construction, maintenance, repair and servicing of all types of rolling stock.

Locomotives

The diesel locomotive today is the backbone of railroad motive power. Yesterday it was the steam locomotive. Tomorrow it may be the steam or gas turbine, or even an atomic-powered unit. The railroads are constantly seeking new and improved methods in a continuing evolution. At the same time, current maintenance problems are always under study.

The Mechanical Department offers opportunities:

To assist in developing means of keeping diesel engines in serviceable condition under many different and difficult operating conditions;

To devise methods of overhauling generators, traction motors and all allied electrical equipment;

To develop and oversee methods of servicing motive power at outlying points in order to keep it in constant service; and on some roads,

To participate in new developments in modern high-speed locomotives which may be electric, gas turbine, diesel–electric, steam turbine, or even atomic powered.

Cars

High-speed passenger and freight train operations have completely changed and multiplied the engineering problems involved in the Mechanical Department. Heavier carloadings and specialized requirements of the railroads' customers have further magnified its problems.

Engineers in the Mechanical Department participate in the design and maintenance of passenger cars capable of operating at speeds in excess of 100 mph. At the same time they must see that all air conditioning, lighting, and safety equipment on these cars function properly under every condition imposed; that wheels, trucks, and electric and air brakes meet the highest safety and comfort standards.

Problems for the engineer to solve in the freight car field are likewise interesting and varied. The Mechanical Department must—

Establish techniques of rebuilding and modernizing freight cars, balancing dollars spent against results obtained;

Devise means to service, inspect and repair cars in trains at terminals, without delays;

Develop and approve bearings, brakes, and safety appliances;

Set up loading rules to prevent derailments;

Foster new practices and better materials to reduce costs or prolong service life.

Electrical Department

The railroad electrical engineer serves as an integral part of the Engineering, Maintenance of Way, and Mechanical Departments, and finds a wide opportunity to apply his training to problems pertaining to fixed plants, and locomotives and cars, as well as to specialized studies that arise from time to time.

The railroad electrical engineer is responsible for the design and maintenance of:

Generators, traction motors, auxiliaries, and control equipment on diesel–electric locomotives, which are of primary importance on the railroads today.

Power supply, air conditioning equipment, lighting, intercommunication systems and other modern electrical conveniences on passenger cars.

Electric features of the fixed plant, which include lighting, power distribution, transmission lines, power substations, electrolysis studies, etc.

Catenary, transmission lines, substations and supervisory control, as well as the many problems of the electric locomotive on electrified lines.

All of these responsibilities call for ingenuity, resourcefulness, and versatility on the part of the railroad electrical engineer.

Other Opportunities In the Railroad Field

The young engineer entering railroad service can select a wide variety of activities outside the scope of the departments already covered. These may be in the:

Research and Test Department
Operating Department
Purchasing Department
Industrial Development Department
Accounting Department
Traffic Department

Many railroads reach into their various technical departments for men for further training and advancement to positions of responsibility in other departments.

Civil, Mechanical, Electrical and Chemical engineering graduates interested in practical research will find opportunities in the **RESEARCH AND TEST DEPARTMENTS** of the railroads. Here one finds up-to-date physical, chemical and metallurgical test laboratories fitted with modern testing equipment and machines designed to assist the purchasing and user departments in the quality control and utilization of the thousands of types of material purchased by the railroads; to check design stresses of locomotives, cars, bridges, buildings, and the track structures; to analyze failures in structural materials, track fastenings, and car and locomotive parts, looking to improved designs, increased safety, and lower costs.

A number of railroads have organized **TRANSPORTATION RESEARCH** departments where all types of engineers analyze shop, terminal, train, accounting, or clerical operations to develop new and improved methods. The work is generally performed in small groups and may be carried through from investigation to execution of suggested changes.

The **OPERATING DEPARTMENTS** of the railroads have found the training and experience of all types of engineers an excellent background for trainmasters, superintendents and other operating personnel; for scientifically analyzing train operations on the road and in terminals; for working out the material-handling problems at large freight stations and storehouses.

The **INDUSTRIAL DEVELOPMENT DEPARTMENTS** of the railroads offer opportunities for Civil, Industrial, Architectural and other types of engineers to assist manufacturers in plant location, layout, and service trackage; to promote industrial growth and traffic through studies of natural resources in the territory served; and to foster agriculture, forestry and stock raising in areas contiguous to railroad lines.

The **ACCOUNTING AND TRAFFIC DEPARTMENTS** also offer increasing opportunities to engineers, as railroad accounting and cost controls assume constantly increased importance and as freight traffic solicitation in the present competitive era becomes more than a matter of rate structure and routing.

In all of those fields, railroad officers are constantly on the lookout for those who have demonstrated ability, resourcefuless, ingenuity, sound judgment and willingness to assume responsibility. These are the men who will later step to the head of their respective departments and eventually into top management positions.

What Special Advantages Do the Railroads Offer Engineers?

In addition to the opportunities offered by the railroads to the young engineer as an outlet for his training, energy and ingenuity, they provide their technical employees attractive compensation, with excellent opportunities for advancement, a high degree of job security, many desirable benefits, and, in many instances, training courses.

Compensation and Advancement

A study made by the American Railway Engineering Association discloses that the average starting salary paid engineering graduates by the railroads is in line with, or slightly above, the average paid by industry generally, and that the minimum railroad salary is well above the minimum reported for all graduates.

Engineering employees who have acquired a proper engineering education, and who disclose personal characteristics of ability, interest, integrity, cooperation and loyalty, have an excellent opportunity for advancement to positions carrying greater responsibility and higher compensation, not only in the various engineering departments, but in any of the other departments into which his preference and aptitude may lead him.

Job Security

Railway transportation is recognized as the safest, most dependable, most economical, and most essential of all the various available forms of land transportation. Consequently, employment within the railway industry has a high degree of stability.

Benefits

Most engineering employees of railway companies have opportunities to travel, not only in connection with their assigned duties, but also during vacation periods, taking advantage of their privilege to secure railway passes or reduced fare transportation for themselves and their families. This privilege continues to be of benefit to railway employees after they retire.

The railroad engineering employee is reimbursed for living expenses (cost of meals and lodging) during periods when engaged in assigned work at locations away from his established headquarters.

Federal laws known as the Railroad Retirement and Railroad Unemployment Insurance Acts protect railway employees and their families against the loss of income due to old age, disability, unemployment, sickness and death. In addition, some of the railroads have set up their own retirement plans which provide officers and supervisors with additional income over that to which they may be entitled under Federal laws.

Some railroads have agreements with insurance companies whereby employees, if they so desire, may participate in low-cost group insurance, including life insurance, accident insurance, and hospital and physician expense insurance.

Some railway companies own and operate hospitals wherein hospital and medical service are available to employees, and their families, at very reasonable cost.

Training Courses

Many railway companies have available so-called student training courses which provide an opportunity for young engineers to work in various departments, such as the Engineering, Maintenance of Way, Mechanical, Electrical, Communications, Signal, etc. Participation in such student training courses will expand the young engineer's knowledge of the railway industry and eventually present an opportunity for advancement.

Some companies have arrangements whereby high school and college students are given employment in various departments during the summer months between school terms.

What Technical Training and Personal Characteristics Are Required For A Railroad Career?

For the engineer entering railroad work, a high degree of specialization is not generally necessary. What is required, is that he be familiar with general engineering techniques, and be able to employ an analytical approach to the solution of railroad problems and to the development of new ideas to add to the adequacy and efficiency of the industry.

Having received an education in General, Civil, Mechanical, Electrical or other engineering in a good engineering school, a man has an ideal foundation for a successful career in railroading. After he has entered railroad work, his advancement depends upon how successfully he is able to apply the learning he has acquired, upon his diligence, and upon his ability to work harmoniously with his associates.

As mentioned before, many railroads have established training courses to train further young technical graduates for responsible railroad supervisory positions. These courses serve to give those participating in them a start on the practical experience they need to make better use of their technical training. Likewise, they give the young engineer an opportunity to find his place in the type of work and position for which he is best suited.

If the Challenge and Opportunity of a railroad career are attractive to you, contact any of the railroad representatives who periodically interview students at engineering schools; or contact any railroad system or division office and make your interest known; or address an inquiry to the Chief Engineer, Chief Mechanical Officer, or the President of any railroad.

Special Report on Annual Meeting of the American Society for Engineering Education, at University of Illinois, June 14–18, 1954

By C. G. Grove*

Early in 1954, the Association of American Railroads became an Associate Institutional Member of the American Society for Engineering Education—the official professional organization for engineering education—which has guided college engineering programs for more than 60 years to their present high level, in the interest of students, the engineering profession, and American business and industry. The AAR's interest in ASEE was appropriately vested in Committee 24—Cooperative Relations with Universities, of the AREA, which designated one of its members—C. G. Grove, chief engineer—Western Region, Pennsylvania Railroad—to act as the AAR's official representative in the Society. In view of this new relationship between the AAR, the AREA and the ASEE, the following brief comments with respect to the Society, particularly its relationship to industry, will be of interest to railroad engineers and railway managements.

The ASEE includes some 7500 Individual Members (college administrators, faculty members, and industrial people); Active Institutional Members (accredited engineering colleges, which include every accredited engineering school in the United States—a total of about 150); Affiliate Institutional Membership (for technical institutes and other accredited sub-professional engineering institutions); and Associate Institutional Membership (which includes more than 70 companies and associations in industry).

The Society feels that industry has an important stake in its activities, and, in turn, offers many tangible benefits to industry. Its overall program gives recognition to the fact that the development of technical managerial talent is a most critical problem facing top management today; that the future prosperity and progress of every industrial concern depends upon a constant flow of people and ideas into the organization. The participation of industry in the Society gives recognition on the part of enlightened management to its partnership with the Universities in maintaining effective programs for the recruitment, training, continued education, and management development of its professional people. As never before, industry looks to the engineering colleges for a source of technical manpower, as well as for a reservoir of fundamental knowledge.

Membership in the Society, such as that maintained by the AAR, provides a channel of communication with the policy makers of the universities, a forum for discussing problems of mutual interest, and the machinery for implementing educational and research programs. It gives the industrial representative a friendly and intimate relationship with college deans and faculty members, and an opportunity to gain an understanding of the problems of colleges and to inform the college personnel of his industry's needs and problems. Furthermore, his association with college faculty members in the common cause of the engineering profession promotes mutual understanding and respect.

Industry's representatives in the Society find participation in its Relations with Industry Division particularly rewarding. This Division is composed of an active group of industrial representatives and college faculty members, and, in addition to building good relations between industry and the colleges, has conducted a number of noteworthy studies on such subjects as industrial training, qualities necessary for success in industry, a speaker's manual, technical job descriptions, selection of college graduates, and graduate study in industry.

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* Chief engineer, Western Region, Pennsylvania Railroad, Chicago, and the Association of American Railroads' representatives in ASEE.

In addition to the activities of the various divisions, the Society holds an annual meeting each year on a college campus, as well as periodical regional meetings at various educational centers of the country. The most recent annual meeting of the Society was held at the University of Illinois, June 14–18, 1954, which was attended by the AAR representative, who reported to Committee 24, in part, as follows:

"The first conference of the Relations with Industry division was held on Tuesday, June 15, with the theme 'Ethics'. This most important aspect of the engineering profession was very ably presented by four speakers, following which there was a general discussion. Subjects touched upon included Organization of Engineers, Code of Ethics of Engineers, and Competitive Bidding by Engineers.

"The next conference was joint with the Engineering College Research Council of the Society on the theme 'Cooperative Research with Industry'. This conference brought out the viewpoint of educational institutions, the viewpoint of industry, and the areas of research cooperation. The great impetus in matters of research is presenting a number of problems for the colleges and universities, and the facts brought out were of great benefit as a guide to industry in providing funds for research projects.

"In addition to the foregoing conferences, your representative, with the knowledge that the railroads of the country have considerable difficulty in recruiting men for minor technical roles, such as design or engineering drawing, attended a conference of 'The Technical Institute Division' of the Society. Members of this division are made up of instructors, professors and deans of technical institutes where young men, in the course of two years, fit themselves for positions as technicians and engineering draftsmen. As a result of this conference it would appear that the railroads might well show a greater interest in these technical institutes and graduates. It has been the experience on many roads that engineering employees with college or university training, ending with a Bachelor of Science in Engineering degree, are not always satisfied to serve on an engineering corps or in a drafting room. The graduates from these technical institutes would probably be better satisfied with such positions, and, at the same time, some of them, due to sheer ability, may progress to positions ordinarily attained by college or university graduates.

"Your representative found the opportunity of meeting and talking with members from colleges and universities, as well as with members from other industries, most stimulating, and from that angle alone the Associate Institutional Membership of the AAR was well worthwhile. In addition, the conferences provided viewpoints and information that should be mutually helpful to the educators and industry in solving many of the problems with which they are confronted."

Report of Committee 15—Iron and Steel Structures

J. F. Marsh, *Chairman,*
P. E. Adams
Raymond Archibald
R. C. Baker
H. A. Balke
E. F. Ball
F. Baron
J. L. Beckel
J. E. Bernhardt
E. S. Birkenwald
R. T. Blewitt
M. Block
H. F. Bober
J. C. Bridgefarmer
R. N. Brodie
E. E. Burch
V. R. Cooledge
E. F. Croxson
R. P. Davis
W. E. Dowling
C. E. Ekberg
G. V. Guerin, Jr.
Shortridge Hardesty
S. C. Hollister
N. E. Hueni
M. L. Johnson
B. G. Johnston
R. L. Kennedy
J. C. King
R. E. Kolm
Shu-t'ien Li
C. T. G. Looney
F. H. Lovell
F. M. Masters
D. V. Messman
James Michalos
K. L. Miner
B. J. Minetti
N. W. Morgan
C. T. Morris (E)
Cornelius Neufeld
N. M. Newmark
J. C. Nichols
R. E. Peck
A. R. Harris, *Vice Chairman,*
A. G. Rankin
W. S. Ray
C. A. Roberts
G. E. Robinson
C. H. Sandberg
T. C. Shedd
L. L. Shirey
C. E. Sloan
H. F. Smith
J. E. South
G. L. Staley
H. C. Tammen (E)
E. K. Timby
J. P. Walton
C. Earl Webb
H. T. Welty (E)
A. I. Wilson
A. R. Wilson (E)
W. M. Wilson (E)
L. T. Wyly
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.
   Revision of Specifications for Steel Railway Bridges, submitted for adoption and publication in the Manual .... page 590
   Digest of tests on the finishing of structural plate edges, presented as information .... page 590
2. Fatigue in high-strength steels; its effect on the current Specifications for Steel Railway Bridges.
   No report.
4. Stress distribution in bridge frames:
   (a) Floorbeam hangers;
   (b) Counterweight trusses of bascule bridges;
   (c) Model railway truss bridge
   Progress report, presented as information .... page 591
5. Design of steel bridge details.
   No report.
6. Preparation and painting of steel surfaces.
   Progress report, presented as information .... page 592
8. Specifications for design of corrugated metal culverts, including corrugated metal arches.
   No report.
9. Use of high-strength structural bolts in steel railway bridges.
   Part 1—1954 inspection of experimental installations presented as information .... page 592
   Part 2—Tightening high-strength bolts, presented as information .... page 599

Part 3—Revision of Specifications for Assembly of Structural Joints Using High Tensile Steel Bolts in Steel Railway Bridges, submitted for adoption and publication in the Manual .... page 631

10. Substitutes for paint for preservation of steel bridge structures.
    No report.
11. Economics of various design loadings.
    No report.

THE COMMITTEE ON IRON AND STEEL STRUCTURES,
J. F. MARSH, *Chairman.*

AREA Bulletin 520, January 1955.

Report on Assignment 1

Revision of Manual

E. S. Birkenwald (chairman, subcommittee), J. L. Beckel, R. P. Davis, A. R. Harris, J. F. Marsh, Cornelius Neufeld, C. H. Sandberg, G. L. Staley.

Your committee offers the following recommendations with respect to Chapter 15 in the Manual.

Pages 15–1–1 to 15–1–43, incl.

SPECIFICATIONS FOR STEEL RAILWAY BRIDGES

Page 15–1–33. In Art. 2, Sec. B, change the percent for "Elongation in 8 in, min"

from $\frac{1{,}500{,}000^*}{\text{tens. str.}}$, to 16*.

Change the percent for "Elongation in 2 in, min" from $\frac{1{,}600{,}000}{\text{tens. str.}}$, to 19.

Digest of Tests on the Finishing of Structural Plate Edges

Because of failures of steel due to brittle fracture, it was felt by your committee that tests on different steels, modified by different end conditions, should develop information which would probably lead to revision of the Manual with respect to the finishing of steel edges. Sponsored by Committee 15, a research program was conducted in the structural research laboratory of the University of Illinois by Dr. L. A. Harris, under the general direction of N. M. Newmark, research professor of structural engineering.

Tests were made under so-called statically applied tensile loads on small specimens of four different types of steel with several different kinds of edge conditioning. The steels used were a rimmed steel and a semi-killed steel, both meeting ASTM A–7 specifications; a structural silicon steel (ASTM A–94); and a low-alloy high-tensile steel (ASTM A–242). The edge conditions used included machined edges, sheared edges, flame-cut edges, and in some cases, flame-cut edges subsequently flame softened. The flame-cut edges were made by both manual and guided flame-cutting techniques.

It is concluded from the tests that for all steels the strength and ductility of machined edges are excellent. For all except the silicon steel the strength and the ductility of the guided flame-cut edges were also very good. However, for the manual flame-cutting procedure, there was, in some cases, serious impairment of the physical properties. Even the automatic flame-cutting technique impaired the properties of the silicon steel, but the ductility and strength were restored by subsequent flame-softening of the edge.

The sheared-edge condition impaired the ductility in all of the steels tested. The greatest damage seemed to be caused in the semi-killed steel where the strength also was reduced for this kind of edge condition, in some instances as low as the yield strength of the material. The damaging effect of the sheared edge was eliminated by subsequent flame-softening treatment. The strength and the ductility were increased to practically the same values as those of the same steel with machined edges.

Brittle fracture was never initiated, under any of the circumstances used in these tests, at stresses below the yield point of the material. Only under the most damaging condition was the strength at a brittle fracture as low as the yield point. With the better fabrication techniques the strength was considerably above the yield point and approached the ultimate strength of the material.

Report on Assignment 4

Stress Distribution in Bridge Frames

(a) Floorbeam hangers
(b) Counterweight trusses of bascule bridges
(c) Model railway truss bridge

C. H. Sandberg (chairman, subcommittee), J. E. Bernhardt, E. S. Birkenwald, J. C. Bridgefarmer, J. F. Marsh, F. M. Masters, N. M. Newmark, G. L. Staley, C. Earl Webb, L. T. Wyly, J. Michalos, E. K. Timby, N. W. Morgan, E. F. Ball.

Your committee submits the following report of progress.

(a)(b) The research project on study and investigation of the causes and remedies of failures in floorbeam hangers in railway bridges and counterweight trusses of bascule bridges is being conducted at Purdue University Engineering Experiment Station under the direction of L. T. Wyly, research professor of structural engineering and head of department. Administration is by Dr. G. A. Hawkins, dean of engineering, and by Prof. K. B. Woods, head of the School of Engineering.

The project is sponsored financially by the Association of American Railroads. The program was initiated upon the recommendation of AREA Committee 15—Iron and Steel Structures, and is supervised by the Subcommittee on Stress Distribution in Bridge Frames. This is a cooperative project, and the research office of the Association of American Railroads, under the direction of G. M. Magee, director of engineering research, and E. J. Ruble, research engineer structures, assists in and advises regarding the work.

In Bulletin 517, September–October 1954, pages 217 to 267, incl. (Proceedings, Vol. 56, 1955, same pages), is published a report on the comparative tests of large full-scale structural joints, one connected with high-strength bolts and other connected with rivets and high-strength bolts.

Final reports on the following projects are yet to be published: Static and Dynamic Tests of the Missouri–Kansas–Texas Railway bridge at Erie, Kan.; Static Tests on the Missouri–Kansas–Texas Railway bridge at Dennison, Tex.; and Static Tests on the Texas and New Orleans Railway bridge at Wax Lake, La. These reports all cover measurements of live load stresses in floorbeam hangers. The field work was done in part by the AAR Research Office and in part by Purdue University.

(c) Final arrangements have been completed during the year for the start of tests on a large 100-ft model truss bridge at Purdue University. Carrying capacity of various members will be determined as well as the ultimate strength of end posts and other compression members bent by dislodged loads.

Report on Assignment 6

Preparation and Painting of Steel Surfaces

R. C. Baker (chairman, subcommittee), A. R. Harris, R. N. Brodie, J. C. King, F. M. Masters, K. L. Miner, N. W. Morgan, R. E. Peck, A. G. Rankin, W. S. Ray, C. A. Roberts, L. L. Shirey, C. E. Sloan, C. Earl Webb.

This is a progress report, submitted as information.

The committee is cooperating with the Steel Structures Painting Council and during the past year inspected and made final ratings on the various painting systems under test on the AAR Painting Test in Chicago.

The committee has also made an inspection of the various painting systems under test on the Missouri Pacific Railroad Brine Drippings Test near Chester and Roots, Ill. All painting systems and protective coatings on test are in excellent condition, except one of the proprietary coatings which shows complete failure after one year of exposure.

The committee has also made an inspection of the service paint test on the Atchison, Topeka & Santa Fe Railway. No ratings or comments can be made at present on these painting systems since they have been in service less than one year.

The committee is cooperating with the Steel Structures Painting Council in the publication of Vol. 2 of the Painting Manual. This publication should be completed during the early part of 1955.

Report on Assignment 9

Use of High-Strength Structural Bolts in Steel Railway Bridges

A. G. Rankin (chairman, subcommittee), R. C. Baker, F. Baron, J. E. Bernhardt, W. E. Dowling, N. E. Hueni, C. T. G. Looney, E. K. Timby.

This is a final report, presented as information, and consists of three parts. Part 1 presents details of the 1954 inspection of experimental installations of high-strength structural bolts in various railroad bridges, and includes significant observations developed therefrom. Part 2 is a report on a method of tightening high-strength bolts in which bolt tension is correlated with turns of the nut from a "finger tight" position. Part 3 presents revised Specifications for Assembly of Structural Joints Using High Tensile Steel Bolts in Steel Railway Bridges.

Part 1

1954 Inspection of Experimental Installations of High-Strength Steel Bolts in Steel Railway Bridges

In 1948 the research staff of the Association of American Railroads installed high-strength structural bolts in 12 different railroad bridges to determine if these bolts would stay tight in particular locations where trouble had been encountered in keeping rivets tight. Additional installations were made in 1950 in three bridges in a northern climate to determine if such bolts were adversely affected by severe winter temperatures. These bolts have been inspected periodically since their installation, and details covering the installation and inspections, such as the railroad, location, number and size of bolts, the date of installation, and the various inspection dates, are shown in Table 1. Progress reports covering the initial installation were published in the Proceedings, Vol. 51, 1950,

TABLE 1—TEST INSTALLATIONS OF HIGH-STRENGTH BOLTS

Railroad	*Bridge No.*	*Location*	*No. of Bolts*	*Diam. Inches*	*Date Installed*	*Date Inspected*
PRR	Runway Ore Dock	Ashtabula, Ohio	24 7	⅞ ¾	*Mar. '48	May '48, Dec. '48 Sept. '49, Aug. '51 Sept. '54
PRR	Runway Ore Dock	Cleveland, Ohio	40 30	⅞ ⅞	*Mar. '48 †Dec. '50	May '48, Dec. '48 Sept. '49, Aug. '51 Sept. '54
PRR	21.98	Bellevue, Del.	100	¾	*Oct. '48	Sept. '49, Aug. '51 Aug. '54
PRR	60.07	Perryville, Md.	32	1	*Oct. '48	Sept. '49
PRR	18.58	Naaman, Del.	30	¾	*Oct. '48	Sept. '49, Aug. '51 Aug. '54
CB&Q	307.32	Albia, Ia.	46	⅞	*Sept. '48	Sept. '49, Aug. '51
CB&Q	284.12	Ottumwa, Ia.	88 30	⅞ ¾	*Sept. '48	Sept. '49, Aug. '51
C&NW	711	Beaver, Ia.	30	⅞	*Nov. '48	Sept. '49, Aug. '51 Aug. '54
CMStP&P	Z312	Byron, Ill.	231	⅞	*Nov. '48	Sept. '49, Oct. '50 Aug. '51, Sept. '54
NYC	73.63	Ade, Ind.	26	⅞	*Oct. '48	Sept. '49, Aug. '51 Sept. '54
AT&SF	121A	Wilbern, Ill.	64	⅞	*Aug. '48	April '49, Sept. '49 Aug. '51, Sept. '54
Southern	151.4	Mt. Carmel, Ill.	319	⅞	*Oct. '48	Sept. '49, Oct. '51 Aug. '54
NP	78.1	Miles City, Mont.	104	⅞	†Nov. '50	Sept. '51, July '54
GN	10.0	Lurgan, N. D.	56	⅞	†Nov. '50	Sept. '51, July '54
GN	23.3	Rogers, Minn.	90	⅞	†Nov. '50	Sept. '51, July '54

*Installations reported in AREA Proceedings, Vol. 51, 1950, page 506.
†Installations reported in AREA Proceedings, Vol. 54, 1953, page 929.

page 506, while the later installations and an inspection of all the bolts were reported in the Proceedings, Vol. 54, 1953, page 929.

In general, the majority of the bolts have proven satisfactory. Although a few of the bolts have apparently lost some of their clamping action, this loss could be due to a re-seating of the steel or improper tightening, since in many of the installations it was very difficult to use the torque wrench.

Details of the recent inspection of the test installations are presented in the following.

Pennsylvania Railroad, Ohio & Western Pennsylvania Dock Company, Ashtabula, Ohio

The experimental high-strength bolts installed in this structure were inspected on September 8, 1954.

This structure carries the machinery used in unloading iron ore from lake barges. A total of twenty-four ⅞-in rivets connecting the stringer to a plate at the panel point and seven ¾-in rivets connecting a gusset plate to a post were replaced in March 1948 by high-strength bolts, the ⅞-in bolts being tightened to a torque of 470 ft-lb and the ¾-in bolts to a torque of 300 ft-lb.

A visual inspection of the bolted connections revealed that only one bolt appeared to be loose, as indicated by rust streaks around the washer. However, there was no indication that movement had occurred between the bolted parts. All the ⅞-in bolts were checked with a torque wrench, and the nuts on only 3 bolts turned at a torque value below 540 ft-lb, one turning at 520 ft-lb, another at 480 ft-lb, and the third, which appeared to be loose from the visual inspection, at 160 ft-lb.

Two of the bolts were removed and examined carefully for any indication of rusting, and it was found that the shank and threaded area of the bolt between head and nut were in excellent condition.

Pennsylvania Railroad, Ohio & Western Pennsylvania Dock Company, Cleveland, Ohio

The experimental high-strength bolts in this structure were inspected on September 9, 1954.

This structure consists of a Hulett ore unloader used in unloading iron ore from lake vessels. In March 1948 the eighteen ⅞-in rivets holding the ends of the crane rails to the top flange of the main girder and the twenty-two ⅞-in rivets in the lateral system of the leg brace were replaced by high-strength bolts and tightened to an approximate torque of 470 ft-lb. In December 1950, 30 more ⅞-in rivets in the crane rail girder were replaced by bolts, of which half were tightened to a torque of 470 ft-lb and the other half to a torque of 600 ft-lb.

The bolts connecting the rails to the girder flanges could not be inspected visually on account of the large amount of grease that had collected on the bolts and rail. However, a visual inspection of the two joints in the lateral system indicated that all the bolts were tight, but that the rivets at the other end of these members were quite loose.

The twenty-two ⅞-in bolts in the lateral system were checked with the torque wrench, and none of the nuts would turn at a torque of 540 ft-lb. The nut on 1 bolt was marked with respect to the bolt and then loosened with a torque of 520 ft-lb. The bolt was then tightened to its original position under a torque of 540 ft-lb. The clamping action of the bolts connecting the rails to the girders was quite erratic, with some of the bolts being quite loose and others retaining their full amount. The installation of these bolts required beveled washers on the upper surface of the rail flange, and no effort was made to slide the bolts and beveled washers to the lower side of the hole. It is quite probable that the loss in clamping action is a result of the beveled washers sliding down on the rail flange.

Pennsylvania Railroad, Bridge 21.98, Bellevue, Del.

The experimental high-strength bolts in this structure, were inspected on August 12, 1954.

This bridge consists of single-track beam spans under 3 tracks and a deck-plate girder span under the fourth track. The beam spans consist of three 24-in I-beams per rail. In October 1948 one-hundred ¾-in rivets connecting the channel diaphragm to the beams were replaced with high-strength bolts and tightened to a torque of 295 ft-lb.

A visual inspection indicated that all the bolts were tight. However, it was observed that 3 of the bolts were missing, 2 from enlarged holes and 1 immediately above. These holes had been enlarged considerably at the time the rivets had been burned out, and at the time the bolts were installed 2 washers had been placed under the nut and head to compensate for the enlarged holes. Of 6 bolts treated in this manner these two were the only ones that had failed.

All of the 97 remaining bolts in this installation were checked with a torque wrench by applying a torque of 360 ft-lb to the nut, and only 4 turned before this torque was attained, these turning at 320 ft-lb. These 4 bolts were re-tightened to a torque of 360 ft-lb.

One of the bolts was removed for a visual inspection, and while the exposed surface of the bolt, nut, and washer was badly rusted for lack of protective coating, the section of the shank and thread of the bolt between the nut and head was free of rust and showed bright metal in the thread.

Pennsylvania Railroad, Bridge 18.58, Naaman, Del.

The experimental bolts in this structure, were inspected on August 12, 1954.

This bridge consists of single-track beam spans under 4 tracks. The beam spans consist of three 20-in I-beams per rail. In October 1948 the thirty ¾-in rivets connecting the channel diaphragms to connection angles and the connection angles to the webs of the beam were replaced by high-strength bolts and tightened to a torque of 295 ft-lb.

A visual inspection of the joints did not reveal any unusual rust spots or slippage of the joints. However, it was noted that 2 of the bolts at the bottom of a diaphragm appeared to be loose, as indicated by rust streaks around the washer.

All of the bolts in this installation were checked with a torque wrench by applying a torque of 360 ft-lb to the nuts, and it was found that only 5 nuts turned at a torque at or below this value, 3 turning at 320 ft-lb, 1 at 280 ft-lb, and 1 at 240 ft-lb. The 2 bolts that appeared to be loose during the visual inspection turned as a unit at 120 ft-lb, but could not be tightened or loosened at 470 ft-lb when the heads were kept from turning.

Chicago and North Western Railroad, Bridge 711, Beaver, Iowa

The experimental high-strength bolts in this structure were inspected on August 4, 1954.

This bridge consists of 2 deck-plate girders, and in November 1948 the 30 loose ⅞-in rivets fastening the cross frame gusset plates to the web stiffners were replaced by high-strength bolts and then tightened to a torque of 470 ft-lb.

A visual inspection of all the joints did not indicate any loose bolts or slippage of the connected parts.

All of the bolts in this installation were checked with a torque wrench by applying a torque of 540 ft-lb to the nuts of the 30 bolts. Twenty-six of the nuts did not turn at the applied torque, while 2 turned at 490 ft-lb, 1 at 470 ft-lb, and 1 at 430 ft-lb. These 4 nuts were re-tightened to a torque of 540 ft-lb.

Chicago, Milwaukee, St. Paul & Pacific Railroad, Bridge Z312, Byron, Ill.

The experimental high-strength bolts in this structure were inspected on September 3, 1954.

This bridge consists of 5 single-track through truss spans. In November 1948 a total of two hundred thirty-one ⅞-in bolts were used to replace the loose rivets fastening the lug angles supporting the bottom lateral bracing to the stringers, the top lateral bracing to the lateral plates, and the lateral bracing to the lateral plates in the bottom chords, and tightened to a torque of 470 ft-lb.

A visual inspection of all the bolts indicated that there was no slippage of the bolts or loose bolts in the bottom laterals. Two bolts in the top laterals appeared to be loose, as indicated by rust around the washer, but they could not be moved by hand. One washer was cracked where the bolt had been installed in a "dished out" hole. Apparently, 7 bolts in the top laterals had fallen out, as the bolts now in place appear to be new.

A total of 36 bolts were checked with a torque wrench by applying a torque of 540 ft-lb to the nuts, and 15 turned at torques varying from 110 to 480 ft-lb, while 2 turned at a torque of 520 ft-lb. The remaining nuts did not turn at the applied torque of 540 ft-lb.

The bolt with the cracked washer was removed for visual inspection, a torque of 520 ft-lb being required to loosen the nut. The washer under the head was rusted to the bolt, with some rusting of the shank. However, after removing the rust the shank diameter was found to be 0.863 in as compared with a nominal diameter of 0.875 in. The hole had several "burned out" areas, and this condition, combined with the cracked washer, may have been the cause for the rusting of the bolt shank.

New York Central System, Bridge 73.63, Ade, Ind.

The experimental bolts in this structure were inspected on September 1, 1954.

This double-track through structure consists of 2 outside plate girders and 1 center plate girder. In October 1948 the twenty-six ⅞-in loose rivets connecting the knee braces to the stiffner angles were replaced by high-strength bolts and tightened to a torque of 470 ft-lb.

A visual inspection of these connections did not indicate any slippage of the joints which would be indicated by a crack in the paint along the edges of the joints. One bolt at the bottom of the connection appeared to be loose, as there were rust streaks below the washer.

All of the bolts in this installation were checked with a torque wrench by applying a torque of 540 ft-lb to the nuts. The bolt that appeared to be loose from the visual inspection turned as a unit at a torque of 240 ft-lb, while the nut on the adjacent bolt turned at a torque of 520 ft-lb. The nuts on the remaining bolts did not turn at the applied torque of 540 ft-lb.

One bolt was removed for visual inspection, and a torque of 600 ft-lb was required to loosen the nut. The shank and threaded length of the bolt between the head and nut were in excellent condition, with no indication of rust.

Atchison, Topeka & Santa Fe Railway System, Bridge 121A, Wilbern, Ill.

The experimental high-strength bolts in this structure were inspected on September 2, 1954.

This double-track bridge consists of single-track beam spans and was new at the time of installation of the bolts in August 1948. Each beam span consists of two 36-in wide-flange beams per rail. and the plate diaphragms between the beams were fastened to the angles with sixty-four ⅞-in bolts. The torque used in installing these bolts was estimated, as it was impossible to use the torque wrench on all the bolts.

A visual inspection of these connections did not indicate any rust, cracked paint or slippage of the bolted members, but did indicate some movement between the angles and the webs of the beams, which are riveted.

On account of the close spacing of the beams only 25 of the 64 bolts could be checked with a torque wrench. The nuts on 12 bolts turned at torques varying from 360 to 520 ft-lb. The nuts on the remaining 13 bolts did not turn at the applied torque of 540 ft-lb.

Southern Railway System, Bridge 151.4, Mt. Carmel, Ill.

The experimental high-strength bolts in this structure were inspected on August 31, 1954.

This bridge consists of five single-track through truss spans and a draw span. A total of three hundred nineteen ⅞-in bolts were used in October 1948 to fasten some new reinforcing plates on the floorbeam hangers at the point where they frame into the pin plates at the top chord, and tightened to a torque of 470 ft-lb.

The bolts at each of the 20 hangers were inspected visually, but no evidence of rust streaks or joint slippage, as indicated by cracked paint, could be found. The heads, nuts, washers, and exposed threads had been painted and were in excellent condition.

On account of the bracing bars, only 170 of the bolts could be checked with a torque wrench on 17 of the hangers. The nuts on 9 of the bolts turned at torques varying from 400 to 480 ft-lb, while the remaining 161 bolts could not be tightened further with the applied torque of 540 ft-lb.

One bolt was removed for visual inspection, and a torque of 600 ft-lb was required to loosen the nut. The shank and threaded length of the bolt between the head and nut were in excellent condition, with no indication of rust. The steel under the washer on one side was still bright. However, some rust was found under the washer on the other side.

During the installation of these bolts, an experimental installation of 6 Elastic Stop Nuts, in place of standard nuts, had been made. These 6 nuts had been tightened in the same manner as the regular nuts and did not turn at the applied inspection torque of 540 ft-lb.

Northern Pacific Railroad, Bridge 78.1, Miles City, Mont.

The experimental high-strength bolts in this structure were inspected on July 22 and 23, 1954.

This bridge consists of a two-span truss bridge carrying a single track. A total of one hundred four ⅞-in rivets were replaced by ⅞-in bolts in November 1950 in the top connection of the floorbeam hangers.

A visual inspection of all the top hanger connections, both bolted and riveted, did not reveal any rust streaks or joint slippage.

All of the bolts were checked with a torque wrench, and it was found that the nuts on 16 of the bolts turned at torques varying from 360 to 240 ft-lb, while the nuts on 41 of the bolts turned at torques varying from 480 ft-lb to 520 ft-lb. The nuts on the remaining 47 bolts did not turn at the applied torque of 540 ft-lb.

The 2 experimental installations of Elastic Stop Nuts in place of standard nuts did not turn at the applied torque of 540 ft-lb.

Great Northern Railway, Bridge 10.0, Lurgan, N. D.

The experimental high-strength bolts in this structure were inspected on July 10, 1954.

This bridge is a single-track through truss span and a total of fifty-six ⅞-in rivets in two of the floorbeam hanger connections at the upper chord gusset plates were replaced by high-strength bolts in November 1950.

A visual inspection of the two bolted connections, and other similar riveted connections, did not reveal any rust streaks or joint slippage. However, some of the bolt heads and washers are rusted on the exposed surfaces.

During the 1951 inspection of this installation a total of 33 bolts were inspected, and it was found that most of the nuts turned at a torque below the installation torque of 470 ft-lb. These 33 bolts were tightened to a specified minimum amount, but the remaining 23 bolts were not checked.

All of the bolts were checked with a torque wrench during the inspection on July 20, 1954, and it was found that 7 of the bolts which had not been previously checked turned at torques varying from 240 to 360 ft-lb. The nuts on 10 of the bolts, some of which had been checked previously and tightened in 1951, turned at torques varying from 400 ft-lb to 440 ft-lb. The nuts on 19 of the bolts turned at torques between 480 and 540 ft-lb which, of course, is above the installation torque of 470 ft-lb. The nuts on the remaining 20 bolts did not turn at a torque of 540 ft-lb.

In general, it appears that the bolts which showed a loss in clamping action during the 1951 inspection and were then re-tightened, have retained their full clamping action.

Great Northern Railway, Bridge 23.3, Roger, Minn.

The experimental high-strength bolts in this structure were inspected on July 19, 1954.

This bridge consists of a single-track draw span and a total of ninety ⅞-in rivets in 3 floorbeam hanger connections at the upper gusset plates were replaced by high-strength bolts in November 1950.

A visual inspection of the 3 bolted connections, and other similar riveted connections, did not reveal any rust streaks or joint slippages.

All of the bolts were checked with a torque wrench, and it was found that the nut on 1 bolt turned at a torque of 360 ft-lb, 1 at 400 ft-lb, and 4 at 440 ft-lb. The nuts on 18 other bolts turned at torques varying from 480 to 520 ft-lb, which is above the installation torque of 470 ft-lb. The nuts on the remaining 65 bolts did not turn at the applied torque of 540 ft-lb.

GENERAL OBSERVATIONS

From the results of this inspection of over 1300 high-strength bolts that have been in service in railroad structures subjected to considerable vibration for periods of 4 to 6 years, the following observations appear significant:

1. The bolted joints have proven superior to the riveted joints.
2. There has been some loss in the clamping action of several of the bolts, possibly due to a re-seating of the steel members.
3. Bolts tightened into the plastic range have stayed tight.
4. Bolts should be tightened considerably higher than the minimum recommended values to provide for a subsequent loss in clamping action.
5. Extremely low temperatures has had no apparent affect on the bolts.
6. The enclosed area of the shank and threads of the bolts that have been properly installed will not rust.

Part 2

Tightening High-Strength Bolts

A. DIGEST

Use of the high-strength bolt as a structural fastener is rapidly gaining favor, as is evidenced by the fact that millions have been used to fasten hundreds of thousands of tons of structural steel. The American railroads having approximately 94,000 steel bridges to maintain, including the re-driving of loose rivets, are offered great potentialities in the use of high-strength bolts. It is possible that high-strength bolts will eventually replace hot-driven rivets in all field erection work. On some railroads field riveting has already been eliminated in favor of this newer type fastener.

To be completely effective, high-strength bolts must be tightened to at least the minimum prescribed bolt tension. When only a few scattered bolts are to be installed at remote sites, it becomes impractical to use power equipment, and hand tools are usually used. A method is needed whereby bolts can be tightened without elaborate equipment and still provide assurance that the bolts will be sufficiently tight.

A method is described in this report whereby turns of the nut from a "finger tight" position is the criterion of bolt tension. The tests on which this method is based were confined to ⅝, ¾, ⅞, 1 and 1⅛-in bolts, and it is shown that at about a ½ turn of the nut these bolts develop minimum tension. It is further shown that additional tightening into the plastic range will not damage the bolt but will actually improve its performance, especially if it is used in a joint subjected to repeated loading. It is suggested, therefore, that these bolts be given 1 full turn of the nut. Since the tests show that 2 to 3 turns of the nut are required to break the bolt or strip the threads, no bolt will be damaged by tightening to 1 turn, unless the bolt is defective.

With 1 full turn as the criterion for bolt tension, bolts may be tightened by hand wrenches or impact wrenches. Tests were made using 6 different impact wrenches to determine their performance on various sizes of bolts at varying air pressures. It was found that fast nut turning was difficult to control, and that 1 full turn in about 10 sec was a good operating speed. By varying the pressure, a given wrench can be used to tighten various sizes of bolts. Since impact wrenches are very sensitive to changes in air pressure, it was found that no definite air pressure figure should be assigned to a particular size of wrench; rather, it is recommended that any convenient pressure be used that will give 1 full turn of the chuck in 10 sec.

Bolt tension is affected by many possible variables in the tightening operation; this method of tightening reduces these effects to the minimum.

B. FOREWORD

AREA Committee 15—Iron and Steel Structures, in recognizing the trend toward a greater use of high-strength bolts in railroad structures, asked the research staff of the Association of American Railroads to conduct a series of tests to evaluate various methods of tightening high-strength bolts and to offer recommendations which would be useful to maintenance crews.

Specifications for the Assembly of Structural Joints Using High-Strength Steel Bolts were prepared by the Research Council on Riveted and Bolted Structural Joints on January 31, 1951, and revised on February 27, 1954. These specifications, with slight modifications, were adopted by AREA Committee 15 and included in the Manual. These specifications establish minimum bolt tension values and corresponding equivalent torque values, but do not prescribe the means by which bolts shall be tightened to obtain these values. In bridge maintenance where isolated rivets are being replaced by bolts, the required tightening can be achieved with manually operated socket wrenches, but where many bolts are involved it would be impractical to tighten each bolt manually, and power equipment in the form of impact wrenches is necessary. Each of the above methods was used in this investigation.

The tests covered in this report were conducted for AREA Committee 15, Iron and Steel Structures, and were carried out under the general direction of G. M. Magee, director of engineering research, Engineering Division, Association of American Railroads.

The conduct of these tests, analysis of data, and preparation of the report were under the direction of E. J. Ruble, research engineer structures. F. P. Drew, assistant research engineer structures, recorded the details of the tests and prepared this report.

C. TEST LOCATIONS

Since most of the testing was performed cooperatively with wrench manufacturers and other agencies, the actual testing was performed at various locations mutually convenient to those involved. The availability of equipment for a particular test also governed the test locations.

Of the total number of bolts used the largest percentage was tested at the AAR Research Center. However, smaller test programs were conducted at the following locations in or near Chicago:

1. Chicago Pneumatic Tool Company office and laboratory.
2. Ingersoll–Rand Company warehouse and laboratory.
3. Mall Tool Company plant and laboratory.
4. Santa Fe Railroad bridge gang car, Corwith Yards.

The investigation was started in April 1954 and continued into October 1954.

D. TEST EQUIPMENT

1. Bolts, Nuts and Washers

All bolts, nuts and washers were furnished to conform to the requirements of the current Specifications for Quenched and Tempered Steel Bolts and Studs with Suitable Nuts and Plain Washers of the American Society for Testing Materials, ASTM A325–53T. All the bolts were identified on the heads by three radial lines, with the bolt manufacturer's letter designation at the center of the head.

In all of the tests the surfaces of the bolted parts in contact with the head and nut washers were parallel; hence only flat circular washers were used. Bolts, nuts and washers were supplied by two different manufacturers.

Approximately 350 bolts were used in this series of tests and, with a few exceptions, the sizes and lengths were as follows:

⅝ by 2½ in and 4½ in,
¾ by 2½ in and 4½ in,
⅞ by 2½ in and 4½ in,
1 by 2½ in, 4½ in and 6½ in, and
1⅛ by 2½ in, 4½ in and 6½ in.

Most railroad bridge and building construction is confined to the ¾, ⅞ and 1-in sizes, but ⅝ and 1⅛-in sizes were introduced to establish values for extreme limits of bolt size. Similarly, bolts for railroad structures usually are not over 4½ in long, but the use of 6½ in lengths in the larger sizes established an extreme for bolt length.

2. Torque Wrenches

Two different types of torque wrenches were used. One type utilizes a spring steel bar with the socket for the nut on one end and a handle on the other. Bending the bar across a graduated scale induces a torque in the bolt as the nut is turned. This type of wrench is graduated in foot pounds to 470, but higher torques can be obtained by lengthening the wrench. This wrench was used mostly on the ⅝, ¾ and ⅞-in bolts.

The other type of wrench utilizes a steel shaft with the socket for the nut attached directly to it. As the nut is turned on the bolt, this shaft is twisted, and the amount of twist is proportional to the torque applied. The mechanism which translates the shaft twist to the dial reading is enclosed in the wrench housing. Three sizes of this type wrench were used. A 1000-ft-lb wrench was used on ⅞-in bolts, a 2000-ft-lb wrench on the 1-in bolts, and a 3000-ft-lb wrench on the 1⅛-in bolts.

3. Impact Wrenches

There are many sizes and makes of impact wrenches on the market today, and while it is admitted that all sizes and makes were not used in these tests, those manufacturers who make wrenches capable of tightening 1⅛, 1 and even ⅞-in bolts are very few in number. It was considered prudent to use wrenches of those manufacturers who could supply the larger sizes. Only air-operated wrenches were used.

The characteristics of individual wrenches vary, but fundamentally each consists of two principal parts, a motor and an impact unit. The motor operates at a speed in proportion to the air pressure. The drive shaft of the motor is connected to a rotating hammer which imparts a rotary impact to an anvil, and the impacts from this anvil are transmitted to the nut to be turned through a closely fitting chuck. When the wrench runs free the chuck turns at its maximum speed, and no rotary impacts are created. But as soon as some resistance to the free running of the chuck occurs, the rotating hammer strikes the anvil, and the rate at which these impacts occur depends upon the type of wrench and the amount of resistance to turning. When the chuck is prevented from turning, the impacts continue at the maximum rate.

Impact wrenches capable of tightening bolts of the sizes used in these tests vary in weight from about 11 to 28 lb. They can be handled easily by one operator.

Sockets used with the impact wrenches were six-point sockets designed to fit closely the hexagon nuts and provide the maximum bearing surface between socket and nut.

All wrench manufacturers have certain size wrenches that they recommend for use with certain sizes of bolts. These recommendations were adhered to, but additional tests were made using other combinations of wrench size and bolt size.

4. Impact Wrench Calibrator

During one series of tests a calibration device developed by the Bethlehem Steel Company was used. This particular device was designed to handle ¾, ⅞ and 1-in bolts, but could probably be adapted to other sizes. It consists of a hydraulic ram and a steel yoke mounted on a steel frame. The device is shown in Fig. 1, where it is being used to calibrate an impact wrench. A bolt may be tightened in this calibrator either with a hand wrench or an impact wrench, and the bolt tension can be read directly on the pressure gage, which has been converted to equivalent bolt tension.

There are other calibration devices, but all accomplish the same purpose, namely, to translate applied torque into equivalent bolt tension.

5. Fabricated Steel Test Plates

In all of these tests the bolts were torqued through flat steel plates and slabs. To simulate and perhaps exaggerate field conditions where fitting up of the material is required, all bolts were tightened through a grip of several thicknesses of ⅜-in steel plate. A typical test plate is shown on Fig. 4A. The number of plies of these ⅜-in plates varied with the bolt size and length, e.g., 2 plates were used with the 1 by 2½-in bolts, but 12 plates were used with the 1 by 6½-in bolts. All holes were 1/16-in larger than the nominal diameter of the bolt. Fitting-up bolts were used in the 7 holes around the edge of the plate. The 4 holes at the center of the plate were used for the various tests. Similar test plates were used with tests involving ⅝-in bolts. As shown in Fig. 2, the assembly of plates was held in position in a bench vise when tightening the ⅝, ¾ and ⅞-in bolts. However, with the 1-in and 1⅛-in bolts the plate assembly was fastened to a building column, as shown in Fig. 3. To determine the contrast between a large number of plate plies and solid grip material, some bolts were tightened through a 3-in steel slab. All grip material was ASTM–A7 steel.

E. TEST PROCEDURE

1. Torque-Turn Relation for Minimum Bolt Tension

In Table 1 are shown turns of the nut for minimum bolt tension for various sizes and lengths of bolts. To obtain these values the bolt was assembled in the test plate with a washer under head and nut. All fitting-up bolts were tightened snug with a hand wrench. The nut of the test bolt was brought up "finger tight" and a chalk mark made on the end of the bolt from the center to the threads and onto the top of the nut. The torque wrench was applied, and the nut was turned until, with the nut in motion, the specified torque was indicated on the wrench. The wrench was removed and the amount of nut turning observed.

2. Torque-Turn Relation for Ultimate Bolt Tension

In Table 3 are shown turns of the nut for ultimate bolt tension when the threads stripped or the shank broke. The curves on Figs. 4B, 5A, 5B, 6A and 6B show this torque-turn relation up to the ultimate. The data were obtained similarly to that for minimum bolt tension except that the torque was read on the torque wrench as the nut moved past ½ turn, 1 turn, 1½ turn, etc., to failure.

All bolts were not tightened to failure; often the wrench was removed when failure was imminent to facilitate removal of the nut before the threads were destroyed. In Table 2 are listed bolts where nut turning was stopped at 2 or more turns.

3. Torque-Tension Relation for Minimum Bolt Tension

These data are shown in Table 5. In this case a bolt was assembled in the calibrator, the nut was run up to "finger tight", and the specified torque applied with the torque wrench. The bolt tension was read on the gage.

4. Time-Turn-Pressure Relation for Ultimate Bolt Tension Using Impact Wrenches

The test set-up to obtain this data varied somewhat among the various tests, but in general was as follows:

1. A ¾-in air hose connected the compressor to the pressure regulator.
2. A short length of ½-in or ¾-in whip hose connected the regulator to the wrench.
3. The pressure regulator was equipped with a pressure gage, but the pressure at the wrench was desired, so a few feet from the wrench a hypodermic pressure gage was inserted into the air line by bending the hose sharply and sticking the needle into the outside of the bend. The needle was inserted at a flat angle in the direction of the air flow so that when removed the hole sealed itself by the internal pressure. In all cases pressure at the wrench was recorded. The indicated pressure drop between the hypodermic gage and the regulator was about 5 psi.

Figs. 7A to 20, incl., show the data obtained with this type of set-up. The bolt was assembled in the test plate and all fitting-up bolts tightened by a short application of the impact wrench. The test bolt was marked on the end as described previously. The wrench chuck had been painted with ¼-turn stripes, and when the chuck was placed over the nut a chalk mark was made on the test plate opposite one of these stripes. A back-up wrench was put on the head to prevent turning until sufficient tension was developed in the bolt after which the back-up wrench was no longer needed. The desired air pressure to the wrench was adjusted at the regulator, the wrench was turned on, and the number of seconds for each ½ turn of the chuck was determined by a stop watch.

F. TEST RESULTS

The purpose of this investigation was to provide the man with the wrench with an effective yet practical method of tightening high-strength bolts. Such a method must be applicable to bridge maintenance where only a few scattered bolts will be installed at remote sites and where power equipment cannot economically be set up. Such a method must also be applicable to those field locations where large numbers of bolts will be installed and impact wrenches can be used. The method must, in other words, enable a man to tighten high-strength bolts with whatever tools he has immediately available. The simpler the method the more ardently he will comply with the requirements. The joint will be more uniform and less will be required of an inspector. The results of this investigation led to the development of such a method.

1. One-Half Turn for Minimum Bolt Tension

The Specifications for Assembly of Structural Joints Using High-Strength Steel Bolts, developed by the Research Council on Riveted and Bolted Structural Joints, establishes a relation between minimum bolt tension and corresponding approximate equivalent torque. If a bolt is tightened with a torque wrench to these prescribed values and the amount of nut turning recorded, it logically follows that another bolt like it can be tightened the same amount by turning the nut the same amount.

Table 1 shows for various sizes and lengths of bolts the amount of nut turning to provide the required minimum bolt tension as prescribed in the aforementioned specifications. From this table it can be seen that ½ turn of the nut represents an average value for the complete range of sizes and lengths. The long bolts apparently require slightly more than ½ turn for minimum bolt tension, while the short bolts require slightly less. The length of the bolt, however, is not necessarily the principal factor in this turn differential. Since the long bolts were tightened through many plies of grip material, some extra nut turning was required to bring the plates into solid bearing. While the long bolts may elongate slightly more due to total elastic strain, most of the strain is restricted to the threaded portion, and for a given size bolt the length of this threaded portion is constant for all lengths up to and including 6 in. The character of the grip material seems to be the principal factor affecting nut turning up to minimum bolt tension. This is particularly evident by comparing the values in Table 1 for a 3-in solid slab grip with those for a plate grip.

The amount of turning was always measured from the "finger tight" position, this being a convenient reference position. Even with a small hand wrench it is easy to apply a ¼ turn, which means that only a ¼ additional, rather than a ½ turn, would result in minimum bolt tension.

The fact that the ½-turn value applies equally as well to 1⅛-in bolts as to ⅝-in bolts can be partially explained by comparing the threads per inch with the stress areas for the various sizes of bolts, as given below.

Bolt Size, Inches	*Threads per Inch*	*Stress Area, Square Inches*
⅝	11	0.2256
¾	10	0.3340
⅞	9	0.4612
1	8	0.6051
1⅛	7	0.7627

A plot of stress areas against threads per inch will produce nearly a straight line. For a given amount of nut turning, the number of threads per inch are a measure of the total strain applied to the bolt. For the small-size bolts the number of threads per inch are large, and hence a given amount of turn products relatively little total elongation or strain. The opposite is true for the large size bolts. However, since the stress areas are in inverse proportion to these total strains, a fairly constant stress-strain relation is maintained through the range of bolt sizes.

2. Turns of the Nut for Ultimate Bolt Tension

Table 3 shows turns of the nut required to cause failure of the bolt either in breaking the shank or stripping the threads.

ASTM A325–53 T stipulates that for each size of bolt the ultimate load of the bolt is equal to the proof load of the nut. So, in torquing bolts to the ultimate, it is possible that failure may occur either in breaking or stripping, and these tests show the type of failure to be about equally divided between the two.

From Table 3 it appears that 2 turns is about a minimum, while 3 turns is about a maximum, with an average of about 2½. While it is impossible to predict the number of turns for failure, 2½ turns represents an average value for the complete range of sizes and lengths. No consistent relation was found between length of bolt and number of turns for failure. Neither is there any relation in grip material, i.e., whether plate plies or solid slabs were used.

3. Torque-Turn Relation for Ultimate Bolt Tension

Figures 4B, 5A, 5B, 6A and 6B show how turns of the nut and torque are related up to the ultimate for each bolt size.

Friction characteristics of each individual bolt vary to such an extent that no two curves are alike, but there are certain significant features of these curves that should be brought out. In general, the curves rise to a maximum at about 1½ turns and then either level off or fall to lower torque values. A point is reached where the nuts continue to turn without further increase in applied torque. This leveling off is probably due to necking of the bolt shank in the threaded portion. Another significant feature of these curves is their general sharp rise to 1 turn, and in many cases most of this rise is between ½ and 1 turn. Since clamping action or bolt tension and torque are closely allied, it appears from these curves that clamping action will not be substantially increased by turning the nut more than 1 turn.

In Figs. 5B, 6A and 6B the sharp fall of some of the curves at 2, 2½ and 3 turns was due to stripping of the threads and a gradual failure. This is contrasted with the curves where the bolt broke, in which case the curve remained level or fell off but little.

4. One Full Turn

It has just been shown that ½ turn of the nut will give minimum bolt tension, but there are several reasons why bolts should be tightened to more than this minimum. In these tests more plies of material were used than would usually be encountered in practice; however, even with this relatively "soft" grip minimum tension was obtained in all cases at less than 1 turn. It appears then that for grip alone 1 full turn would insure at least minimum bolt tension.

Bolts that have been tightened to minimum tension have a tendency to lose a small amount of their tension as the joint is worked in service. If these bolts are re-tightened they do not then lose their tension. Therefore, if bolts are given 1 full turn there should be no reason to re-tighten bolts to restore tension.

One full turn produces a high prestress in the bolt, which is of considerable advantage, particularly in joints subjected to repeated loading. Fatigue tests were recently conducted at the University of Illinois in which the bolts had been tensioned by turning the nuts 1½ turns. With a stress on the net section varying from 20,000 psi tension to 20,000 psi compression, the joints withstood more than 2,000,000 cycles of loading. One joint which had the contact surfaces coated with grease withstood more than 2,000,000 cycles of stress varying from 0 to 30,000 psi without slipping into bearing on the bolts.

In a shear-type joint the load is carried in friction rather than bearing; hence any method by which friction can be increased will produce a stronger joint. In this type of joint the stress in the bolts does not change with load on the joint, so a high prestress does not mean that the bolt is more likely to fail in service. On the contrary, the high prestress will increase its fatigue life.

Bolts tensioned to 1 turn are stressed in the plastic range. This was demonstrated by backing off the nut after 1-turn tensioning. It was found that permanent set in the amount of about ½ turn had been formed. The bolt was not damaged and could be re-tightened to 1 turn from this new zero and still be a safe, serviceable fastener. Table 4 shows the results of measuring diameters before and after 1-turn tightening.

5. Use of Impact Wrenches

Where there are many bolts to tighten it will usually be found expedient to use impact wrenches. These wrenches reduce the physical effort of the tightening operation and do it faster than other methods. Air-driven or electric impact wrenches can be purchased, but this investigation was confined entirely to the pneumatic type.

When the calibration is done by the type of calibrating device used in these tests, the real purpose is to permit the operator to get the "feel" of his wrench when it is impacting for proper tension as shown on the gage. Air pressure to the wrench is adjusted until the proper tension is obtained in a reasonable period of time of, say 10 sec. When the operator has the "feel" of his wrench he is then ready to tighten bolts on the structure. Calibration is usually required only at the beginning of the day, unless there is a change in set-up, such as different sizes of bolts, additional hose, etc.

In using the calibrator on these tests it was observed that to secure minimum bolt tension the nut turned 2 to 2½ times. This was due to the compressibility of the hydraulic system. Bolts tightened to this same tension in plate material require only ½ turn of the nut.

The present methods of using impact wrenches make it mandatory that the wrenches be calibrated because the output of a wrench is very sensitive to air pressure and time, which reflect directly on resulting bolt tension.

Just what effect air pressure has on various impact wrenches can be seen by inspection of Figs. 7A to 20, incl. These curves represent the performance of six different impact wrenches while tightening various sizes and lengths of bolts at varying degrees of air pressure.

It was concluded early in the test program that if 1 full turn of the nut is to be the criterion for bolt tension, the operator of the impact wrench must be able to watch the mark on his chuck and be able to anticipate his wrench shut off at one turn of the chuck. This means that the chuck must turn slowly and steadily. Ten seconds appeared to be a good operating speed. The curves shown in Figs. 7A to 20, incl., represent variations of air pressure to secure 1 turn of the nut in about 10 sec.

Several significant features are evident in these curves. They are as follows:

a. Regardless of the size of bolt or wrench used, ½ turn of the nut was obtained in less than 5 sec. This applied over a wide range of air pressures. Usually this ½ turn came in 2 or 3 sec, which is entirely too fast for an operator to observe and control bolt tightening. A few exceptions to this occurred, but a very low pressure was used.

b. There is a definite change in the slope of most of the curves between 0 and 5 sec, indicating a reduction in the rate of nut turning. This slowing down of the chuck is due probably to what has been commonly referred to as wrench "stall." However, when this point is reached the nut does not stop but continues to turn at a relatively constant rate, which eventually breaks the bolt or strips the thread.

c. The general slope of the curves after about ½ turn is between 30 and 45 deg from the horizontal. The flatter the curve is, the slower the turning; if the curve is horizontal the chuck had stopped turning completely. The slope of these curves indicates that there was no wrench "stall."

It has already been shown on Figs. 4B to 6B, incl., that applied torque and consequent bolt tension remain fairly constant after about 1 turn. If a wrench is capable of turning a nut once in 10 sec, it seems unlikely that it will "stall" during further turning.

d. Frictional variation between different bolts makes it impossible to secure completely consistent results, but it can be noted in all of these figures that high pressures cause fast nut turning and low pressures slow nut turning.

e. By varying the air pressure the same wrench can be used to tighten several sizes of bolts. In Fig. 7A, for instance, wrench "F" required about 54 psi to tighten ⅝-in bolts to 1 turn in 10 sec, but on ¾-in bolts, Fig. 8B, 58 psi was required, and on ⅞-in bolts, Fig. 12A, 65 psi was required. Similarly, wrench "E" was used on ⅝, ¾, ⅞ and 1-in bolts (Figs. 7B, 9A, 11B and 16A), and by increasing the pressure from 42 psi for the ⅝-in bolts to 55 psi for the ¾-in, 75 psi for the ⅞-in, and 80 psi for the 1 in, this 1 wrench was adequate for all 4 bolt sizes. Hence, by adjusting the air pressure 1 wrench can be used over a wide range of bolt sizes.

f. It was stated earlier that 1⅛-in bolts are not a common size for ordinary structural work, and it was found in these tests that only 1 wrench was capable of tightening 1⅛-in bolts to 1 turn in 10 sec. The flat curves shown in Figs. 18A to 20, incl., indicate insufficient pressure and very slow nut turning for this size of bolt.

It would be possible to select an optimum air pressure for an individual wrench by repeated tests on a calibrator, but such a pressure would only apply to that one wrench. Other wrenches of the same type and make might require more or less pressure. A wrench that has been well maintained will operate differently than one that has been neglected. It seems difficult, then, if not impractical, to assign a definite air pressure figure at which a certain wrench will operate for a certain size of bolt. Such a figure could only serve as a guide to the operator. So many factors enter into the tightening operation that the pressure to be used cannot be predetermined and should not be the governing criterion for bolt tension.

In assembling a joint with high-strength bolts it is essential that the various steel parts be brought together to a solid bearing. Drift pins may be required to line up the holes, but field reaming is not necessary as long as the bolts can be entered into the holes. High-strength bolts can be used as fitting-up bolts and re-used in the final assembly.

The following procedure can be used in assembling a joint:

1. Install fitting-up bolts and tighten as required to bring the parts together.
2. Install bolts in the balance of the holes, tighten the nuts finger tight, then give nuts one full turn.
3. Loosen the fitting-up bolts, re-tighten finger tight and give these nuts one full turn.

Variation in bolt tension can be attributed to any of the following:

a. The operator.
b. The material being bolted.
c. The bolts being used.
d. The kind of wrench being used.

All of these variables are present in one degree or another in all tightening operations; they cannot be eliminated.

However, if bolts are tightened by the turn-of-the-nut method, say 1 full turn, variation "a" is eliminated as long as the operator can follow the mark on his chuck. Variation "b" is eliminated because once the material is fitted up the grip is constant throughout the joint. Variation "c" is eliminated because nut turning requires only that the threads per inch be maintained constant. Variation "d" is eliminated because any wrench can be used that will turn the nut 1 full turn. If impact wrenches are used, any pressure that will produce 1 full turn in about 10 sec is the only requirement.

G. CONCLUSIONS

From the data obtained in these tests and from the analysis of the results it appears reasonable to make the following conclusions:

1. For ⅝, ¾ and ⅞-in bolts in lengths from 2½ to 4½ in, and for 1 and 1⅛-in bolts in lengths up to 6½ in, minimum bolt tension will be obtained in ½ turn of the nut if measured from a finger tight position.

2. In the range of bolt sizes and lengths given above, bolts may be given an average of 2½ turns of the nut before failure by breaking the shank or stripping the threads. Two turns is about the minimum and 3 turns a maximum.

3. One full turn of the nut for the bolt sizes and lengths tested will insure at least minimum bolt tension without damage to the bolt.

4. Impact wrenches provide a fast and effective means of tightening high-strength bolts.

5. When using impact wrenches, 10 sec for 1 full turn is a good operating speed.

6. Impact wrenches should be operated at controlled air pressure with an air regulator in the line.

7. An impact wrench that can make 1 full turn of the nut in 10 sec will not "stall".

8. One impact wrench can be used to tighten several different bolt sizes by adjusting the air pressure.

9. Impact wrenches need not be calibrated.

H. ACKNOWLEDGEMENT

In the performance of the tests it was necessary to enlist the help of the following organizations. Without their cooperation and interest this program could not have been developed.

1. The Santa Fe Railroad for furnishing a bridge gang, tools and equipment.

2. The Ingersoll Rand Company for furnishing impact wrenches and miscellaneous equipment.

3. The Chicago Pneumatic Tool Company for furnishing impact wrenches and other necessary equipment.

4. The Mall Tool Company for demonstrating their impact wrenches.

5. The Bethlehem Steel Company for furnishing a calibrator, impact wrench and torque wrench.

6. The Snap-On Tools Corporation for furnishing torque wrenches.

7. The American Bridge Division of U. S. Steel Corporation for furnishing steel plate material.

8. The Gary Screw and Bolt Division of Pittsburgh Screw and Bolt Corporation for furnishing high-strength bolts.

9. Russell, Burdsall and Ward Bolt and Nut Company for furnishing high-strength bolts.

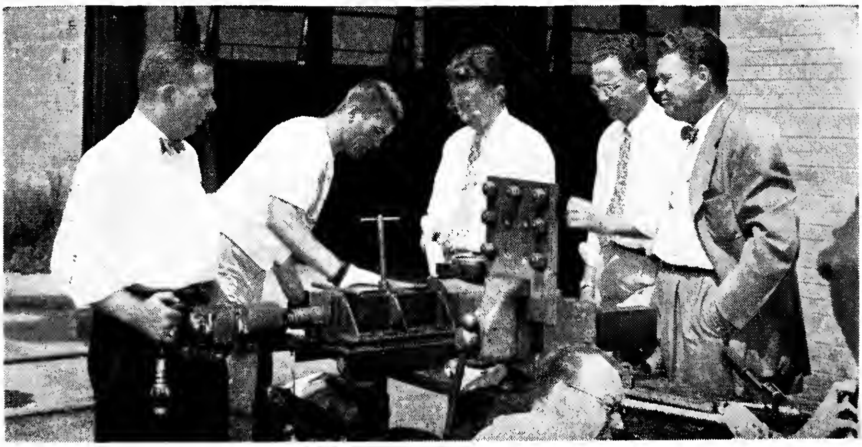


Fig. 1—Calibrating an impact wrench with a hydraulic calibrator before tightening experimental high-strength bolts.

Fig. 2—Determining the relation between air pressure, time, and turns of the nut in tightening experimental high-strength bolts.

Fig. 3—Determining the relation between torque and turns of the nut on 1⅛-in bolts with a 3000 ft-lb torque wrench.

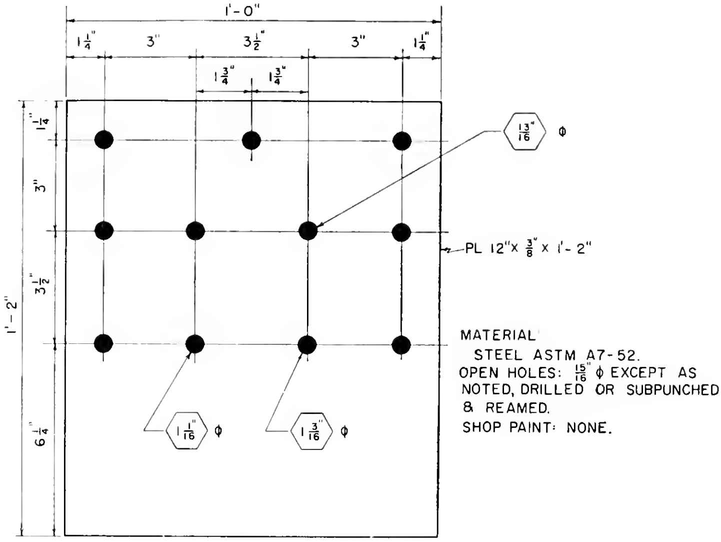


FIG 4A TYPICAL TEST PLATE FOR TIGHTENING BOLTS

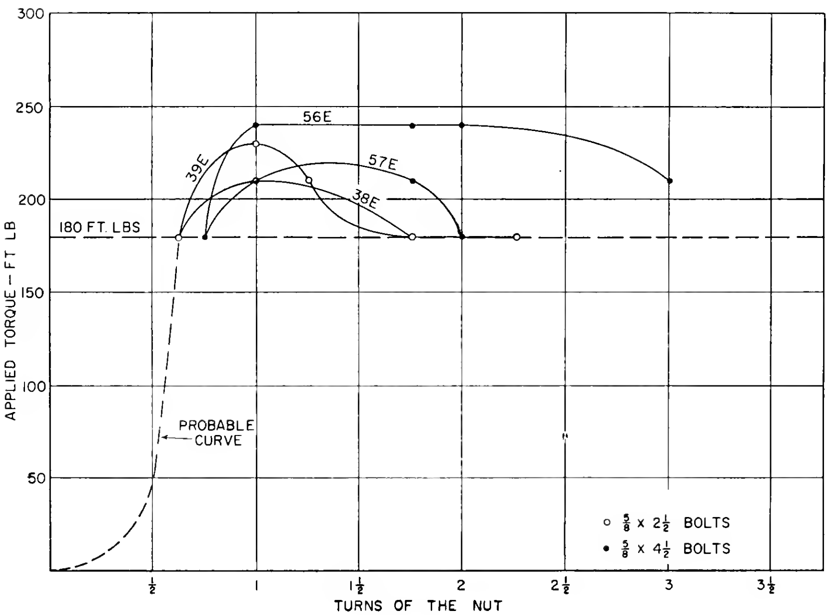


FIG. 4B

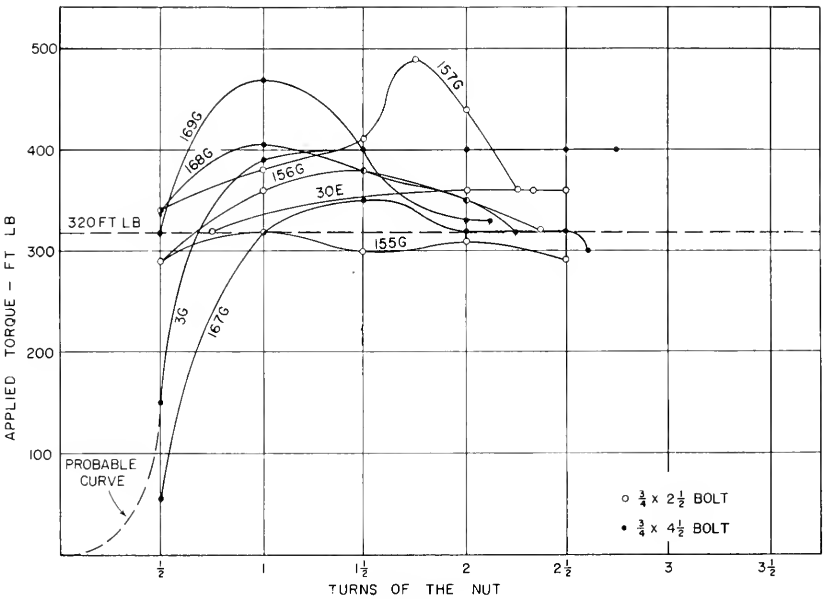

APPLIED TORQUE - FT LB
500
400
320 FT LB
300
200
100
PROBABLE CURVE
157G
169G
168G
156G
30E
155G
3G
167G
○ 3/4 x 2 1/2 BOLT
• 3/4 x 4 1/2 BOLT
1/2
1
1 1/2
2
2 1/2
3
3 1/2
TURNS OF THE NUT

FIG 5A

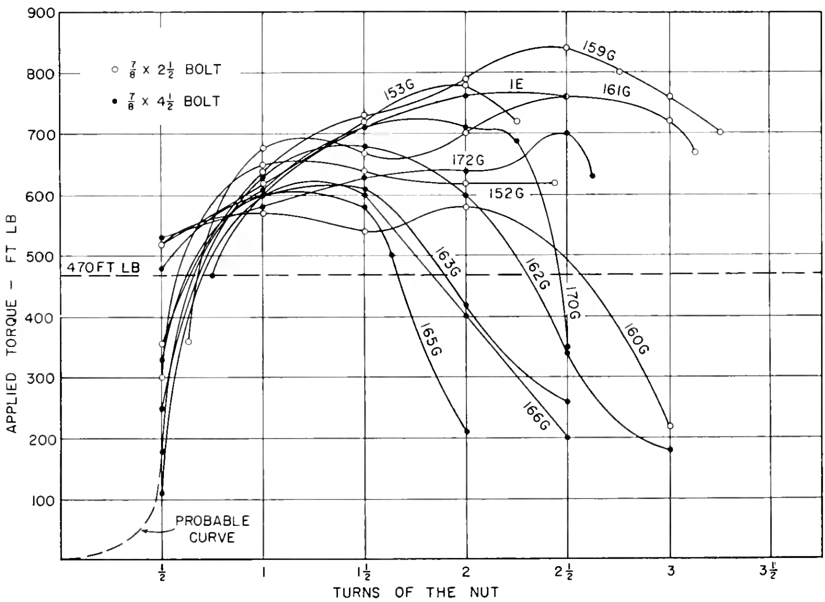

APPLIED TORQUE - FT LB
900
800
700
600
500
470 FT LB
400
300
200
100
○ 7/8 x 2 1/2 BOLT
• 7/8 x 4 1/2 BOLT
159G
153G
1E
161G
172G
152G
163G
162G
170G
160G
165G
166G
PROBABLE CURVE
1/2
1
1 1/2
2
2 1/2
3
3 1/2
TURNS OF THE NUT

FIG. 5B

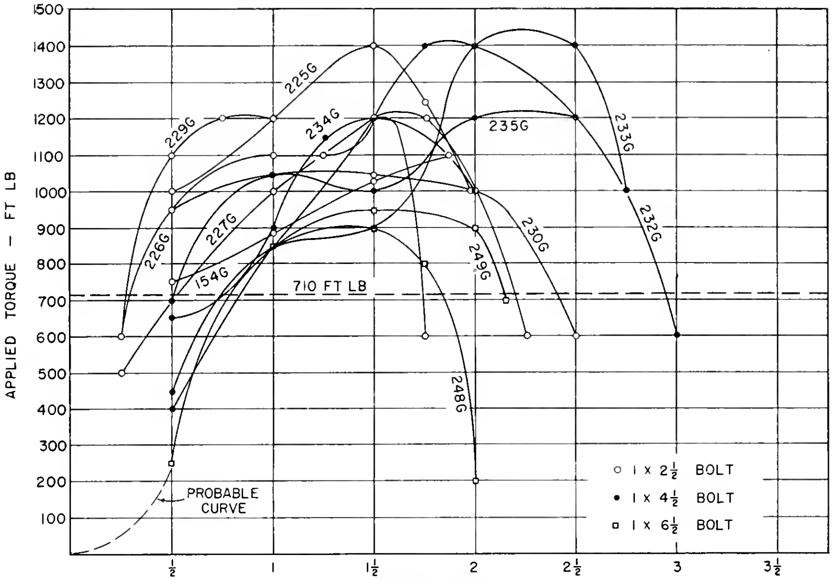

1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
APPLIED TORQUE - FT LB
225G
229G
234G
235G
233G
232G
230G
249G
248G
226G
227G
154G
710 FT LB
PROBABLE CURVE
○ 1 x 2½ BOLT
• 1 x 4½ BOLT
□ 1 x 6½ BOLT
½
1
1½
2
2½
3
3½
TURNS OF THE NUT

FIG 6A

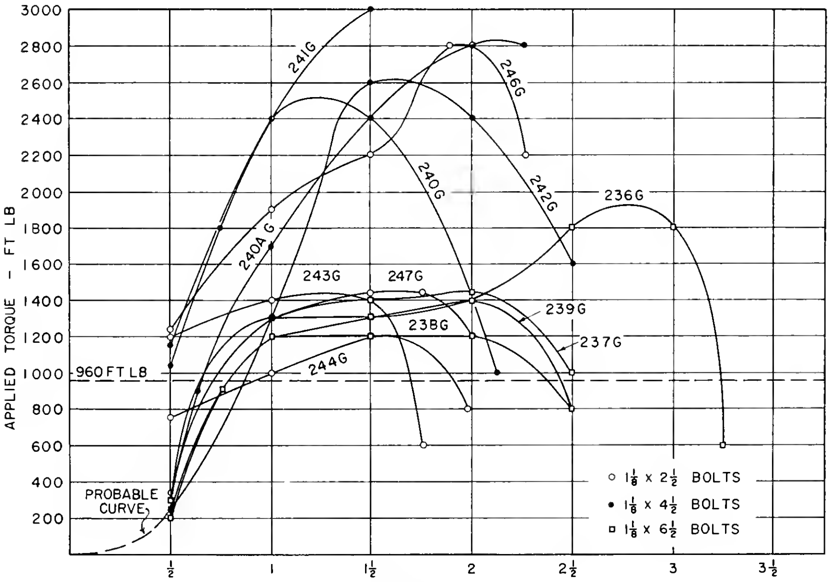
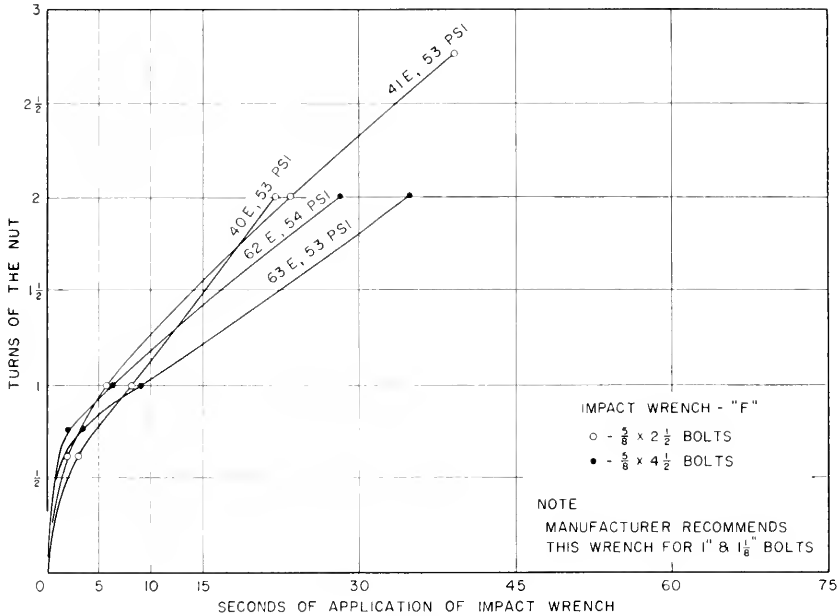
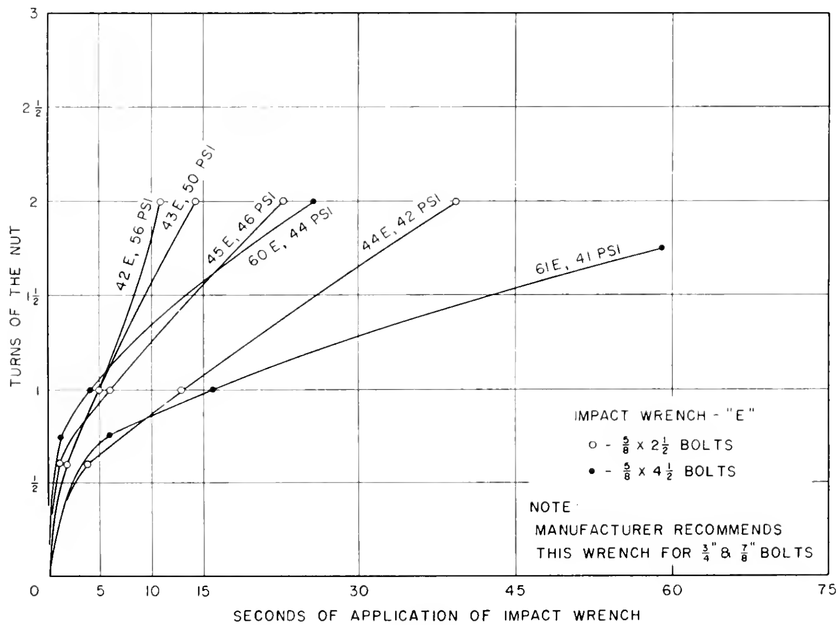

3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
APPLIED TORQUE - FT LB
241G
246G
240G
242G
236G
240A G
243G
247G
239G
238G
237G
244G
960 FT LB
PROBABLE CURVE
○ 1⅛ x 2½ BOLTS
• 1⅛ x 4½ BOLTS
□ 1⅛ x 6½ BOLTS
½
1
1½
2
2½
3
3½
TURNS OF THE NUT

FIG. 6B



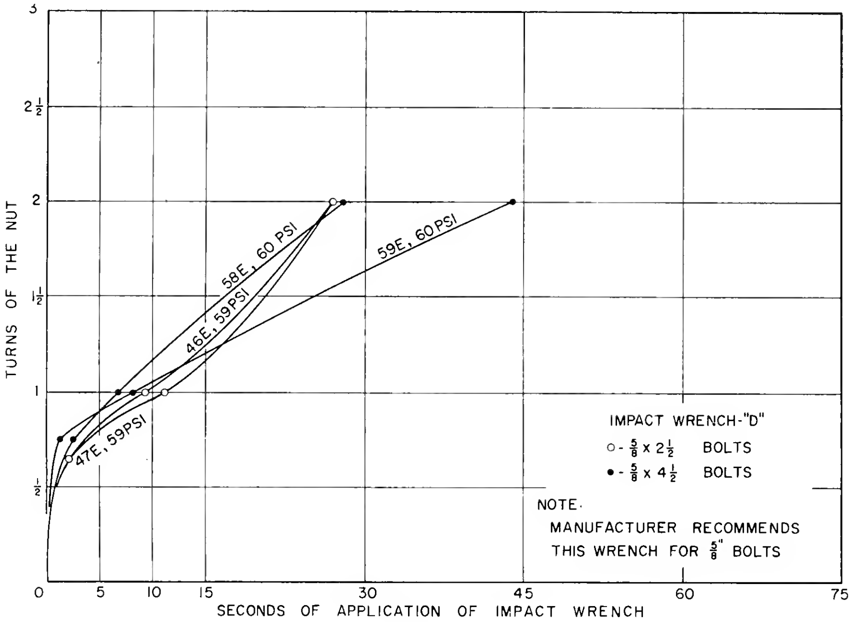
TURNS OF THE NUT
3
2 1/2
2
1 1/2
1
1/2
0
5
10
15
30
45
60
75
SECONDS OF APPLICATION OF IMPACT WRENCH
41E, 53 PSI
40E, 53 PSI
62 E, 54 PSI
63 E, 53 PSI
IMPACT WRENCH - "F"
○ - 5/8 x 2 1/2 BOLTS
● - 5/8 x 4 1/2 BOLTS
NOTE
MANUFACTURER RECOMMENDS
THIS WRENCH FOR 1" & 1 1/8" BOLTS

FIG 7A



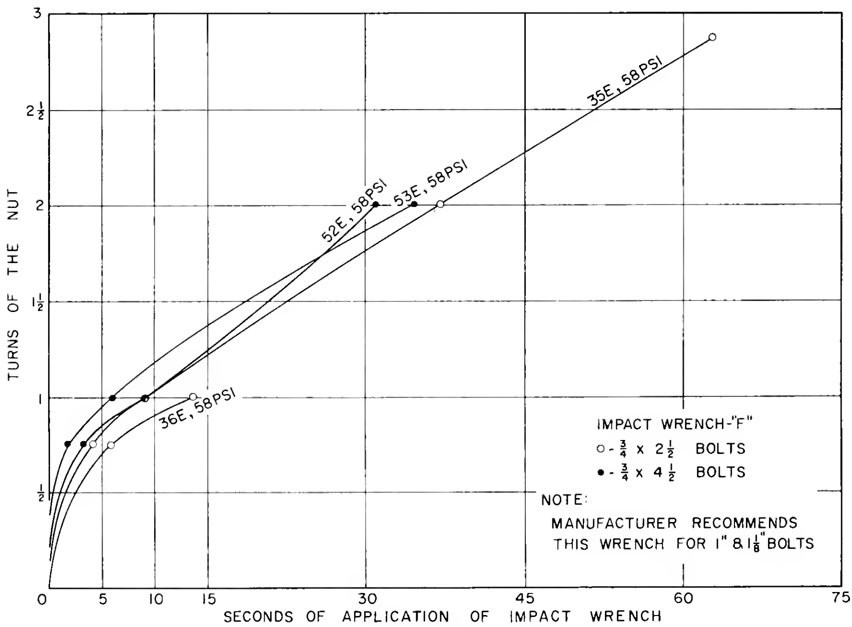
TURNS OF THE NUT
3
2 1/2
2
1 1/2
1
1/2
0
5
10
15
30
45
60
75
SECONDS OF APPLICATION OF IMPACT WRENCH
42 E, 56 PSI
43 E, 50 PSI
45 E, 46 PSI
60 E, 44 PSI
44 E, 42 PSI
61E, 41 PSI
IMPACT WRENCH - "E"
○ - 5/8 x 2 1/2 BOLTS
● - 5/8 x 4 1/2 BOLTS
NOTE
MANUFACTURER RECOMMENDS
THIS WRENCH FOR 3/4" & 7/8" BOLTS

FIG 7 B



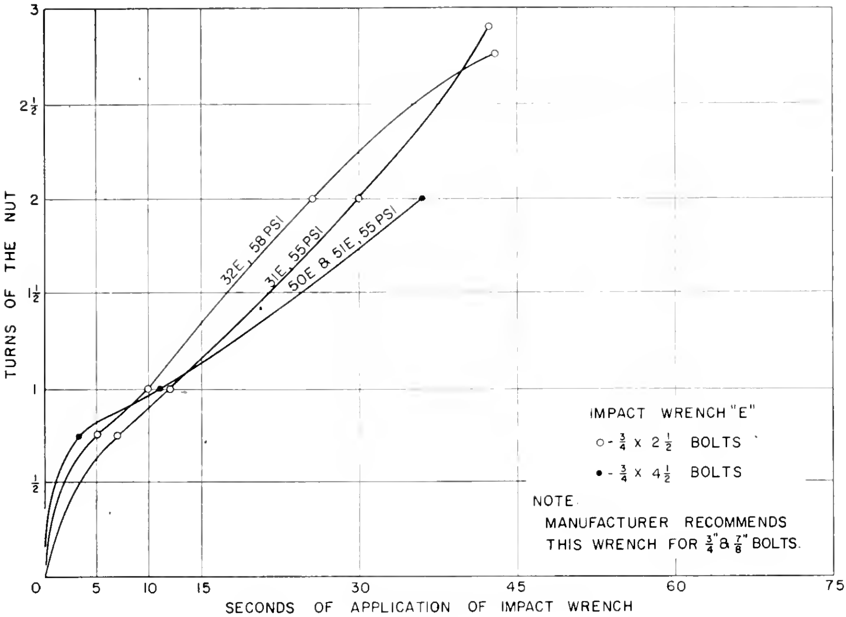
TURNS OF THE NUT
0
1/2
1
1 1/2
2
2 1/2
3
0
5
10
15
30
45
60
75
SECONDS OF APPLICATION OF IMPACT WRENCH
58E, 60 PSI
59E, 60 PSI
46E, 59 PSI
47E, 59 PSI
IMPACT WRENCH-"D"
○ - 5/8 x 2 1/2 BOLTS
● - 5/8 x 4 1/2 BOLTS
NOTE.
MANUFACTURER RECOMMENDS THIS WRENCH FOR 5/8" BOLTS

FIG. 8A



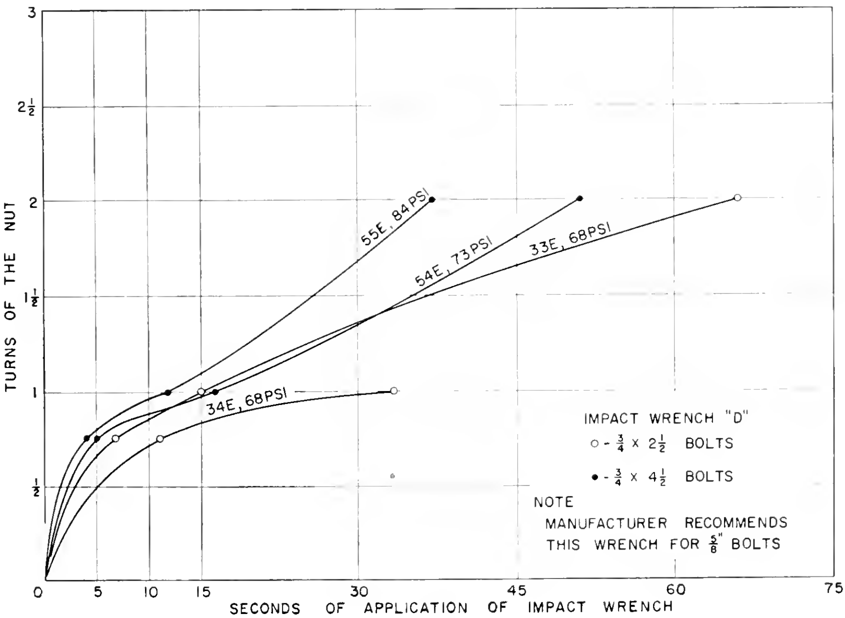
TURNS OF THE NUT
0
1/2
1
1 1/2
2
2 1/2
3
0
5
10
15
30
45
60
75
SECONDS OF APPLICATION OF IMPACT WRENCH
35E, 58 PSI
52E, 58 PSI
53E, 58 PSI
36E, 58 PSI
IMPACT WRENCH-"F"
○ - 3/4 x 2 1/2 BOLTS
● - 3/4 x 4 1/2 BOLTS
NOTE:
MANUFACTURER RECOMMENDS THIS WRENCH FOR 1" & 1 1/8" BOLTS

FIG. 8B



TURNS OF THE NUT
3
2½
2
1½
1
½
0
5
10
15
30
45
60
75
SECONDS OF APPLICATION OF IMPACT WRENCH
32E, 58 PSI
31E, 55 PSI
50E & 51E, 55 PSI
IMPACT WRENCH "E"
○ - ¾ x 2½ BOLTS
● - ¾ x 4½ BOLTS
NOTE
MANUFACTURER RECOMMENDS
THIS WRENCH FOR ¾" & ⅞" BOLTS.

FIG 9A



TURNS OF THE NUT
3
2½
2
1½
1
½
0
5
10
15
30
45
60
75
SECONDS OF APPLICATION OF IMPACT WRENCH
55E, 84 PSI
54E, 73 PSI
33E, 68 PSI
34E, 68 PSI
IMPACT WRENCH "D"
○ - ¾ x 2½ BOLTS
● - ¾ x 4½ BOLTS
NOTE
MANUFACTURER RECOMMENDS
THIS WRENCH FOR ⅝" BOLTS

FIG. 9B

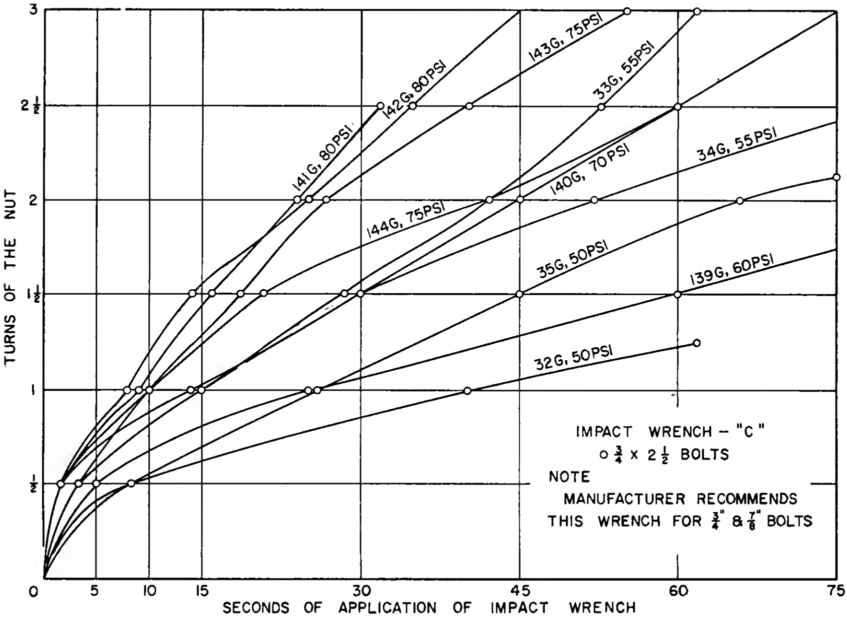


FIG. 10A

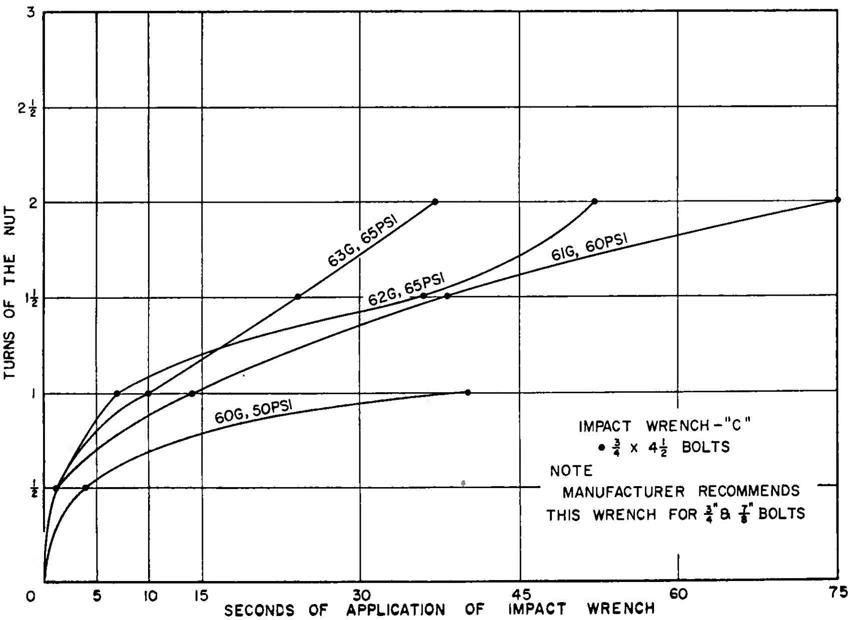


FIG. 10B

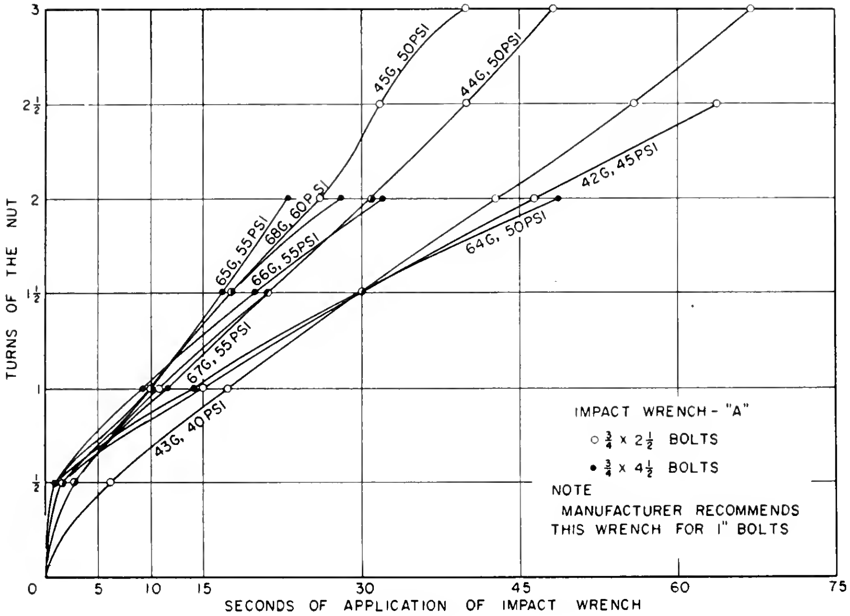


FIG 11A

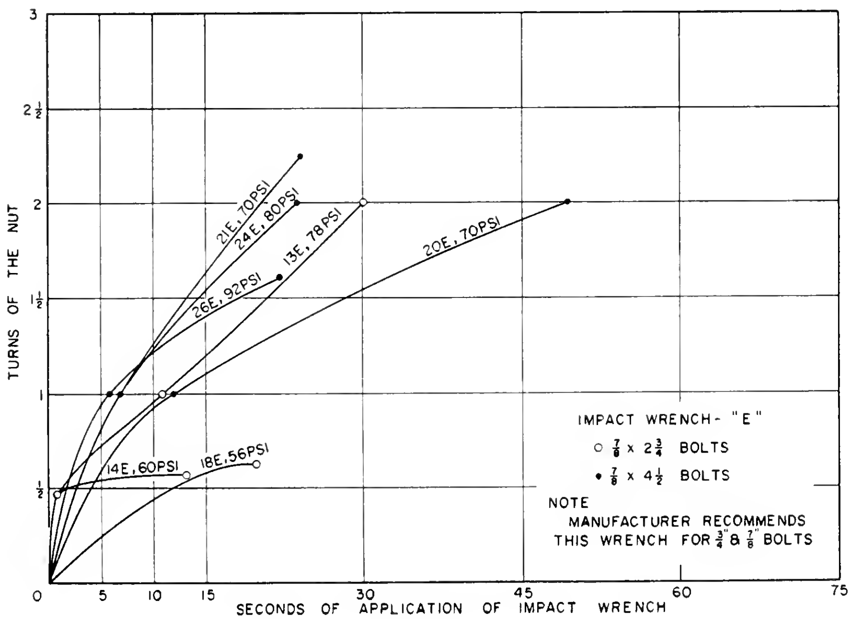


FIG 11B

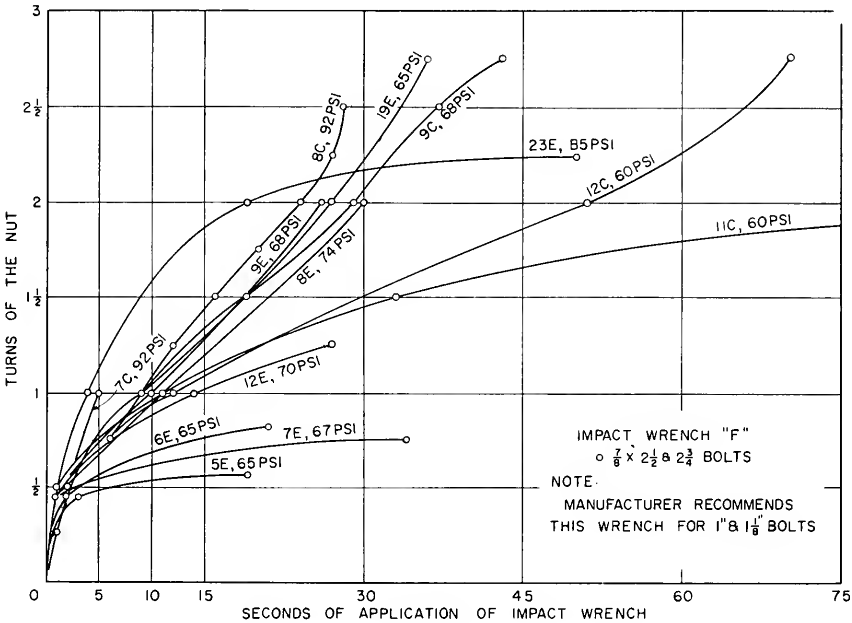


FIG. 12A

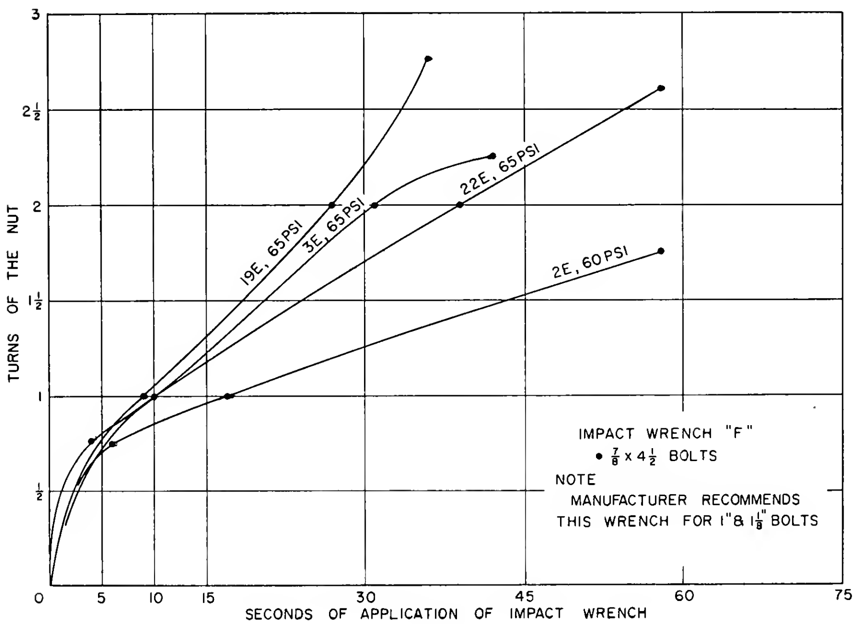


FIG 12B

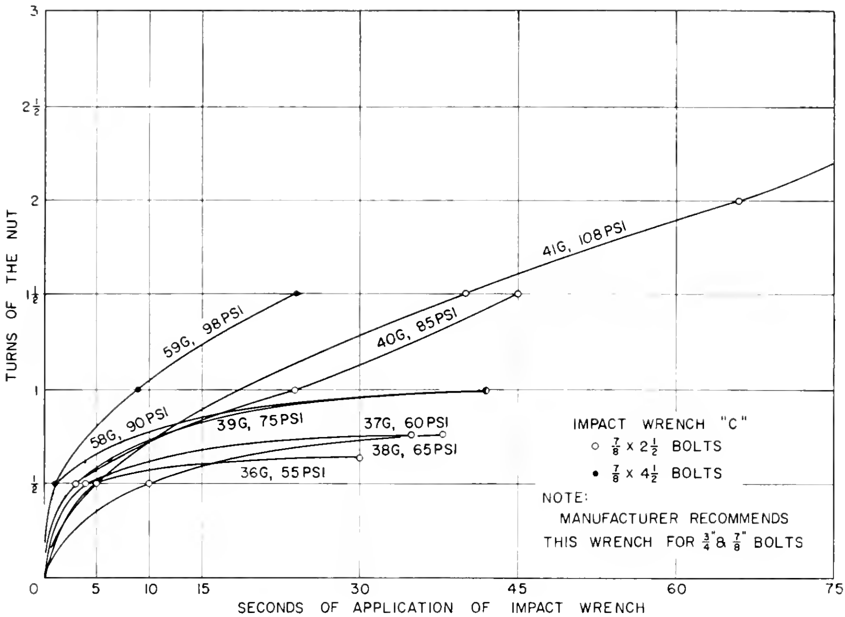


FIG. 13A

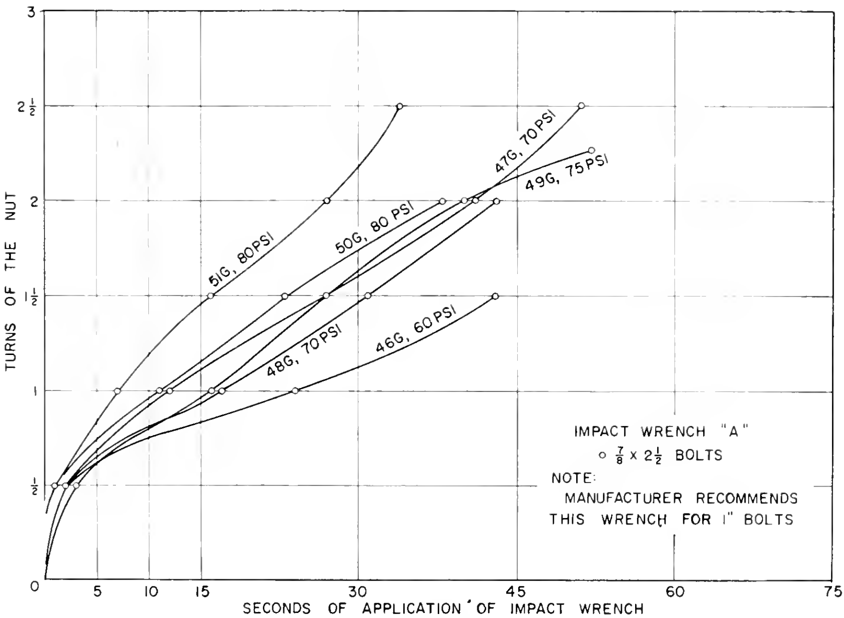


FIG. 13B

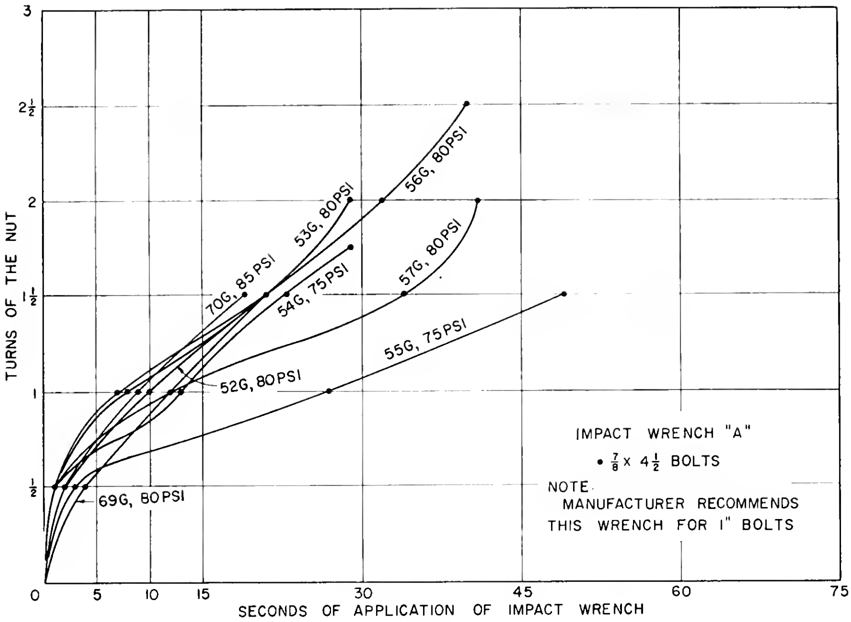


FIG. 14A

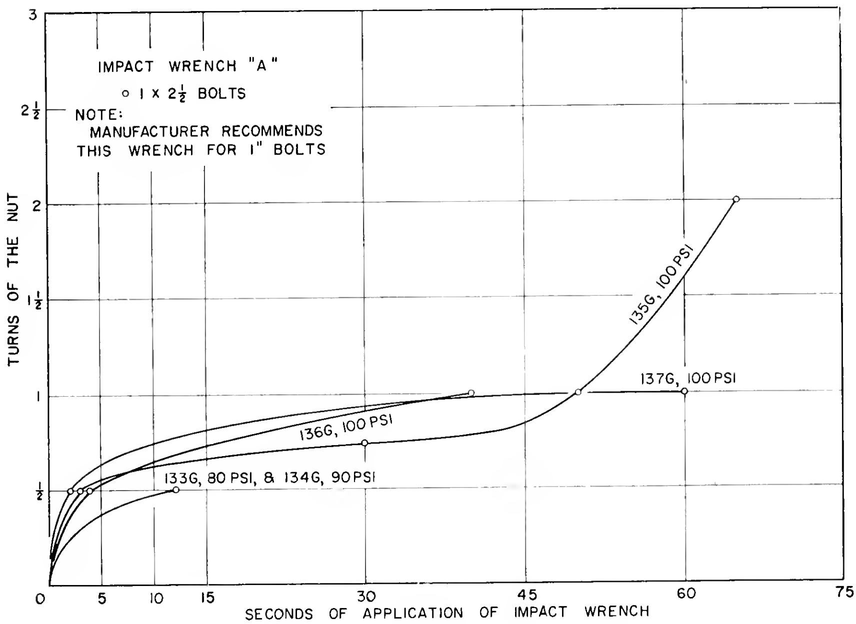


FIG. 14B

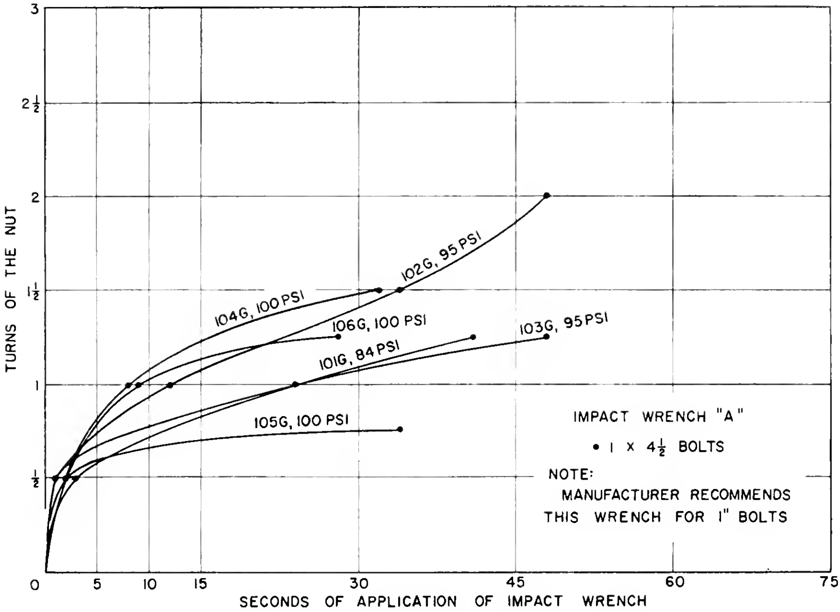


FIG. 15 A

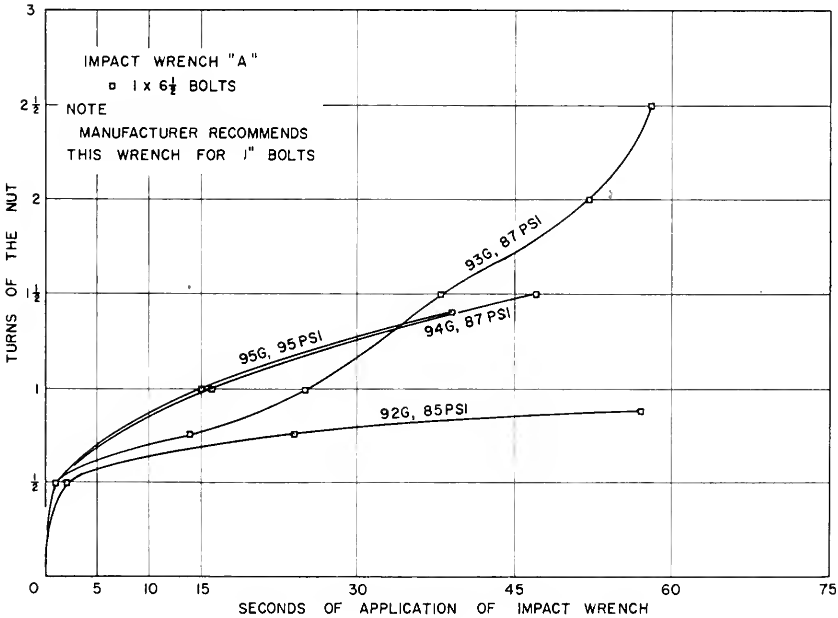


FIG. 15 B

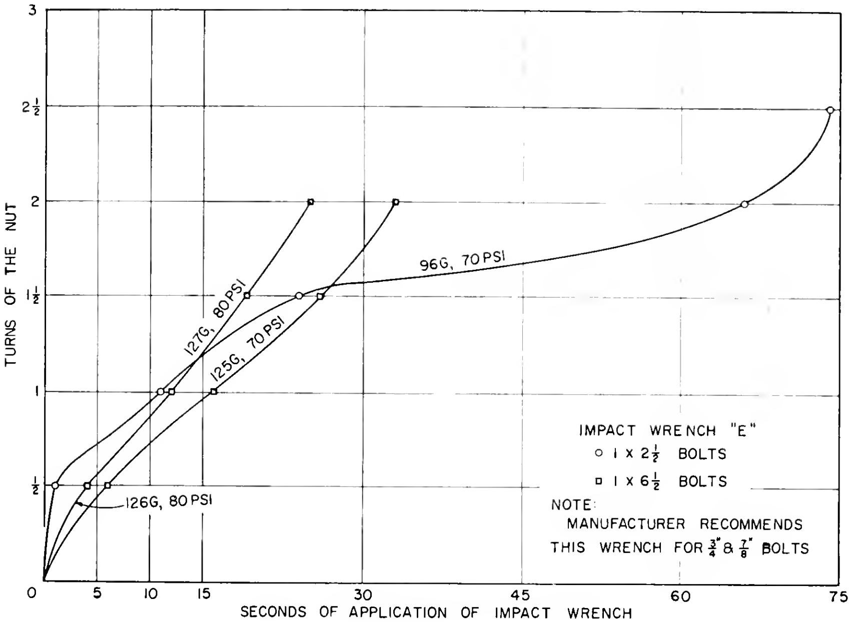


FIG 16A

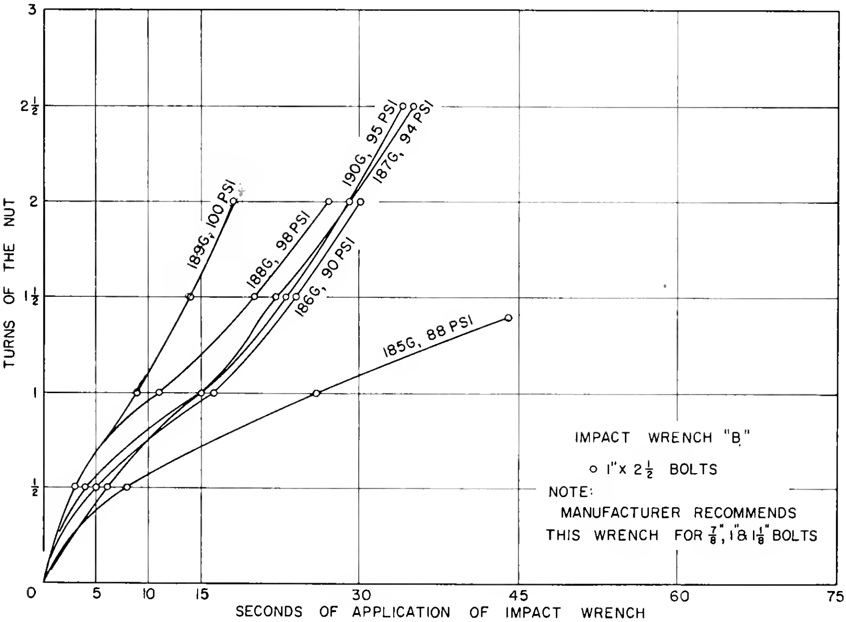


FIG. 16B

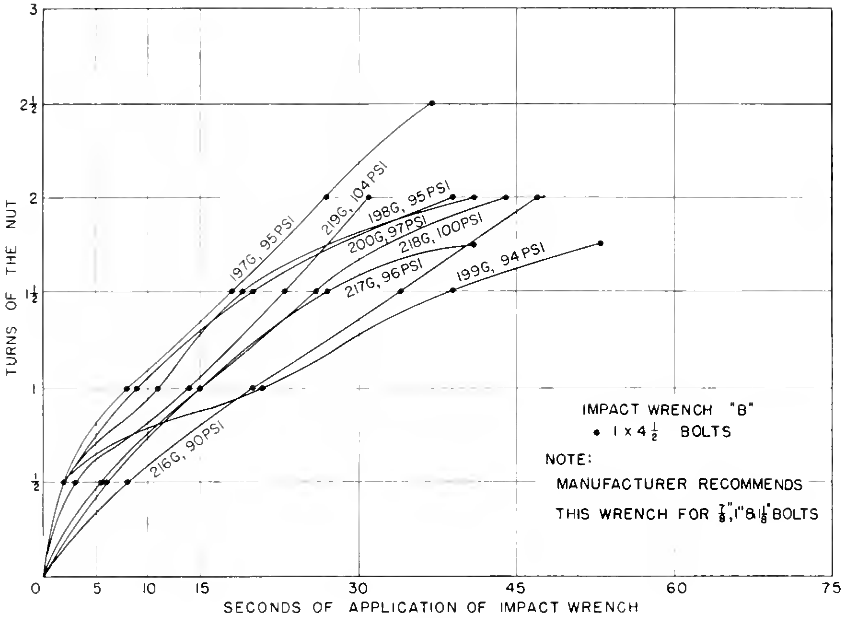


FIG 17 A

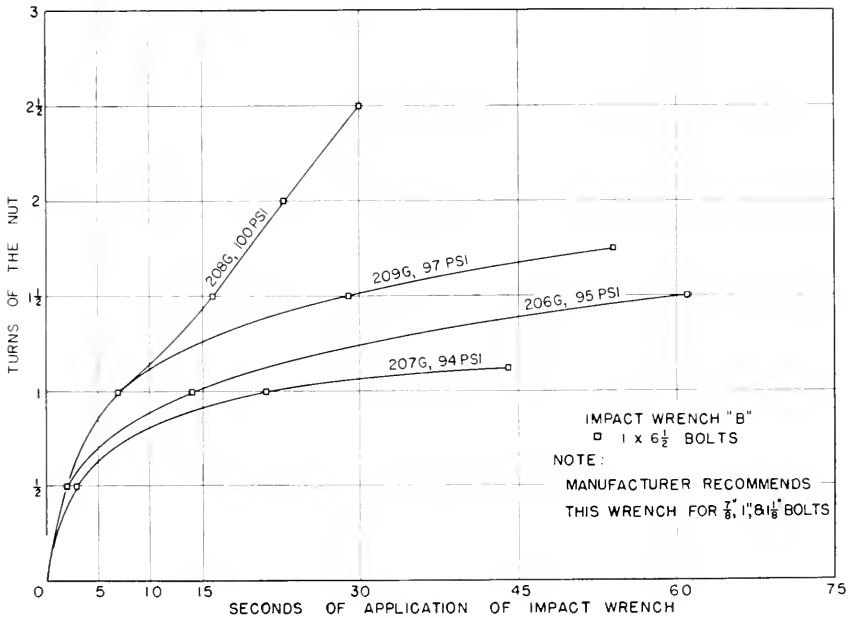


FIG 17 B

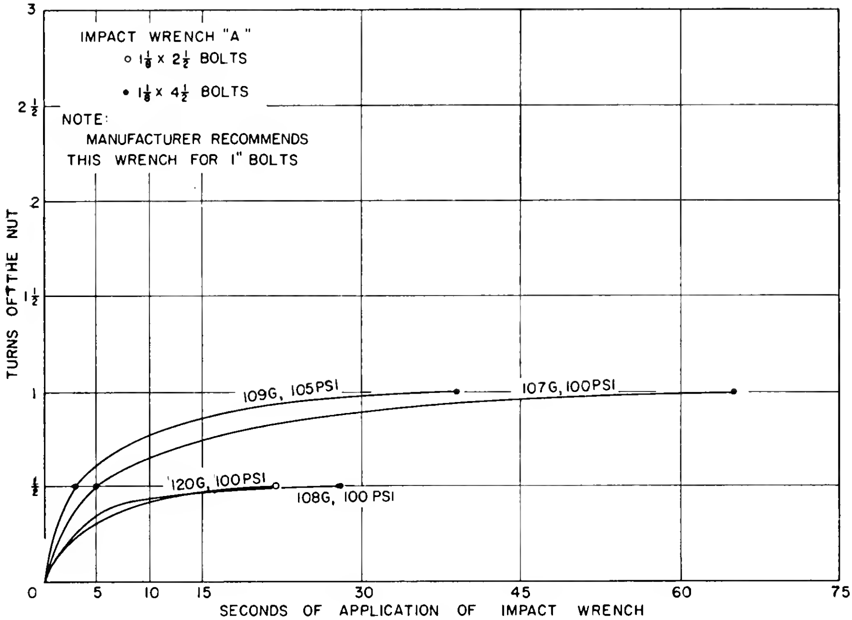


FIG. 18A

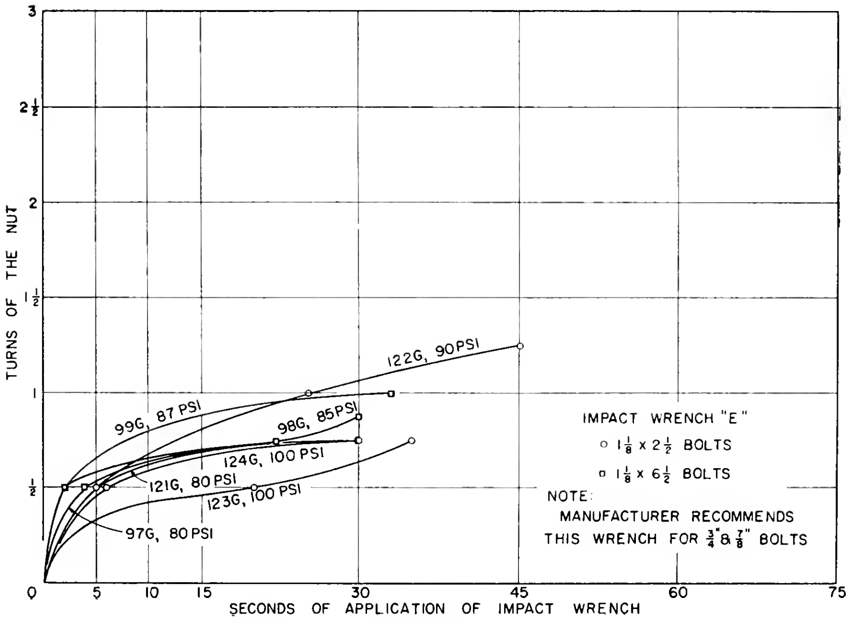


FIG 18B

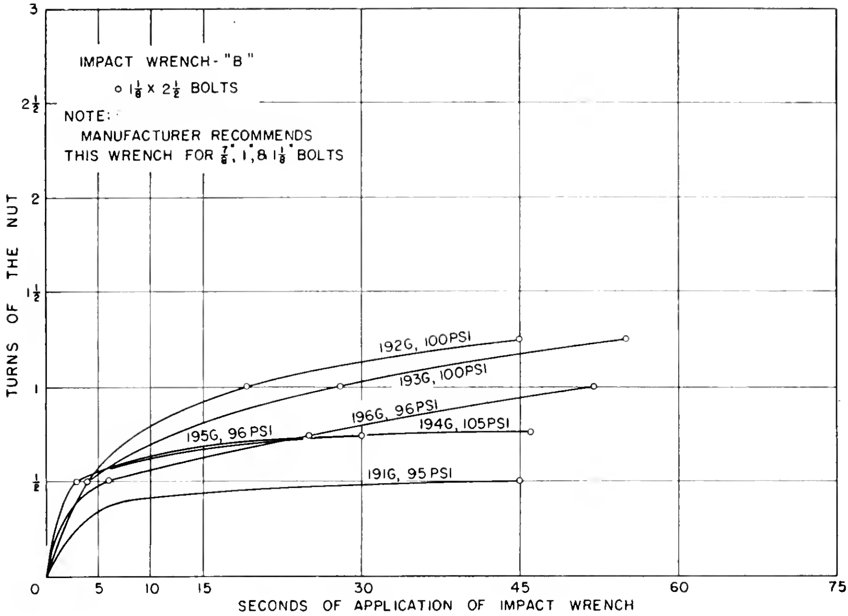


FIG 19A

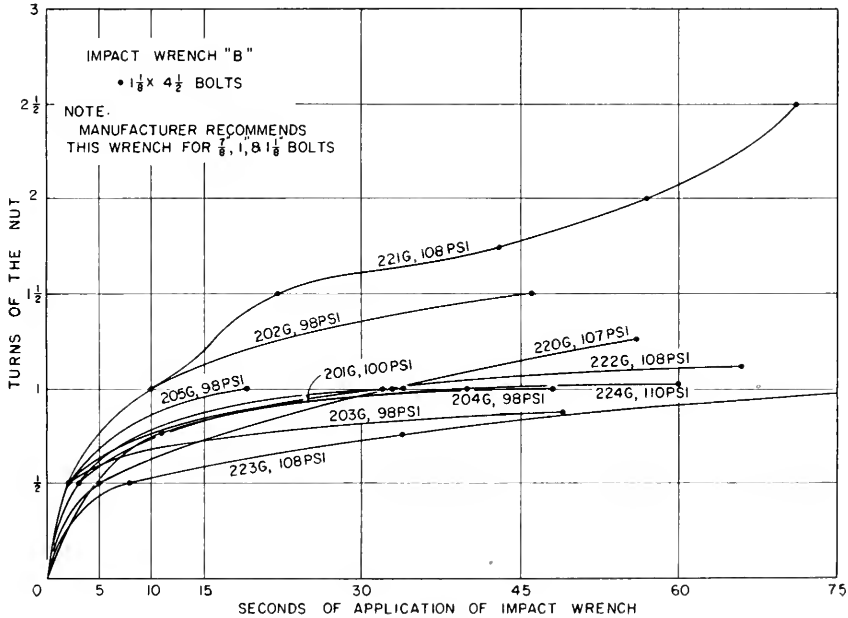


FIG 19B

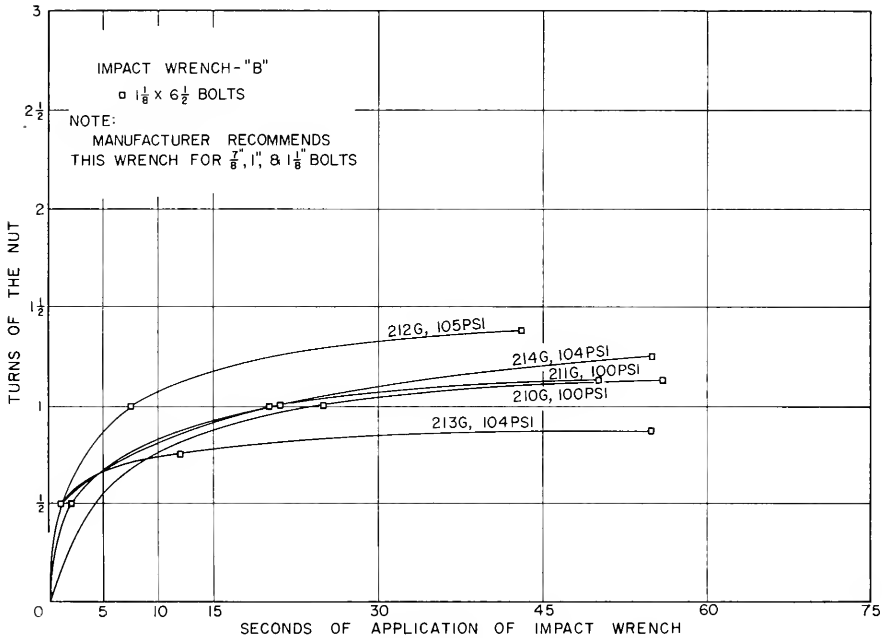

IMPACT WRENCH-"B"
□ 1 1/8 X 6 1/2 BOLTS
NOTE:
MANUFACTURER RECOMMENDS
THIS WRENCH FOR 7/8", 1", & 1 1/8" BOLTS
TURNS OF THE NUT
3
2 1/2
2
1 1/2
1
1/2
0
5
10
15
30
45
60
75
212G, 105PSI
214G, 104PSI
211G, 100PSI
210G, 100PSI
213G, 104PSI
SECONDS OF APPLICATION OF IMPACT WRENCH

FIG. 20

TABLE 1

TURNS OF THE NUT FOR MINIMUM BOLT TENSION

BOLT MARK	SIZE AND LENGTH	TURNS OF THE NUT
38E	$\frac{5}{8}\phi \times 2\frac{1}{2}$	$\frac{5}{8}$
39E		$\frac{5}{8}$
56E	$\frac{5}{8}\phi \times 4\frac{1}{2}$	$\frac{3}{4}$
57E		$\frac{3}{4}$
27E	$\frac{3}{4}\phi \times 2\frac{1}{2}$	$\frac{7}{16}$
28E		$\frac{7}{16}$
29E		* $\frac{15}{16}$
30E		$\frac{3}{4}$
36E		$\frac{7}{16}$
13G		$\frac{1}{2}$
14G		$\frac{5}{8}$
15G		$\frac{7}{16}$
48E	$\frac{3}{4}\phi \times 4\frac{1}{2}$	$\frac{3}{4}$
49E		$\frac{7}{8}$
50E		$\frac{5}{8}$
3G		$\frac{3}{4}$
10G		(S) $\frac{1}{2}$
11G		$\frac{3}{8}$ (S)
16G	$\frac{7}{8}\phi \times 2\frac{1}{2}$	$\frac{1}{2}$
17G		$\frac{3}{8}$
18G		$\frac{7}{16}$
8G	$\frac{7}{8}\phi \times 4\frac{1}{2}$	$\frac{5}{8}$
9G		$\frac{5}{8}$
12G		$\frac{3}{8}$ (S)
110G	$1\phi \times 2\frac{1}{2}$	$\frac{5}{16}$
111G		$\frac{3}{8}$
112G		$\frac{5}{16}$
113G		$\frac{3}{8}$
114G		$\frac{3}{8}$
145G	$1\phi \times 4\frac{1}{2}$	$\frac{3}{8}$ (S)
146G		(S) $\frac{3}{8}$
147G		$\frac{3}{8}$ (S)
71G		$\frac{1}{2}$
72G		$\frac{5}{16}$
73G		$\frac{1}{2}$
74G		$\frac{1}{2}$
83G	$1\phi \times 6\frac{1}{2}$	$\frac{5}{8}$
84G		$\frac{5}{8}$
85G		$\frac{5}{8}$
115G	$1\frac{1}{8}\phi \times 2\frac{1}{2}$	$\frac{5}{16}$
116G		$\frac{5}{16}$
117G		$\frac{7}{16}$
118G		$\frac{5}{16}$
119G		$\frac{5}{16}$
128G	$1\frac{1}{8}\phi \times 4\frac{1}{2}$	$\frac{1}{2}$
129G		$\frac{1}{2}$
130G		$\frac{7}{16}$
131G		$\frac{3}{8}$
148G		(S) $\frac{1}{2}$
149G		$\frac{3}{8}$ (S)
150G		(S) $\frac{1}{4}$
151G		$\frac{3}{8}$ (S)
86G	$1\frac{1}{8}\phi \times 6\frac{1}{2}$	$\frac{5}{8}$
87G		$\frac{1}{2}$
88G		$\frac{1}{2}$

* MISALIGNED HOLES

TABLE 2

TURNS OF THE NUT FOR BOLT TENSION GREATER THAN MINIMUM BUT LESS THAN ULTIMATE

BOLT MARK	SIZE AND LENGTH	TURNS OF THE NUT
38E	$\frac{5}{8}\phi \times 2\frac{1}{2}$	$2\frac{1}{4}$
39E		$2\frac{1}{4}$
42E		2
43E		2
44E		2
45E		2
46E		2
47E		2
59E	$\frac{5}{8}\phi \times 4\frac{1}{2}$	2
60E		2
62E		2
63E		2
33E	$\frac{3}{4}\phi \times 2\frac{1}{2}$	$2\frac{1}{2}$
42G		$2\frac{1}{2}$
140G		3
50E	$\frac{3}{4}\phi \times 4\frac{1}{2}$	2
51E		2
52E		2
53E		2
54E		2
55E		2
4G		$2\frac{5}{8}$
61G		2
62G		2
63G		2
64G		2
66G		2
67G		(S) 2
68G		2 (S)
34G	$\frac{7}{8}\phi \times 2\frac{1}{2}$	$2\frac{1}{2}$
35G		$2\frac{1}{8}$
41G		$2\frac{1}{2}$
47G		$2\frac{1}{2}$
48G		2
49G		$2\frac{1}{2}$
50G		2
3E	$\frac{7}{8}\phi \times 4\frac{1}{2}$	$2\frac{1}{4}$
57G		2
125G	$1\phi \times 2\frac{1}{2}$	2
102G	$1\phi \times 4\frac{1}{2}$	2
198G		2
200G		2
219G		2 (S)

MINIMUM BOLT TENSION DETERMINED WITH TORQUE WRENCH:

- $\frac{5}{8}$" BOLTS TORQUED TO 180 FT LB
- $\frac{3}{4}$" BOLTS TORQUED TO 320 FT LB
- $\frac{7}{8}$" BOLTS TORQUED TO 470 FT LB
- 1" BOLTS TORQUED TO 710 FT LB
- $1\frac{1}{8}$" BOLTS TORQUED TO 960 FT LB

NOTES

ALL NUTS "FINGER TIGHT" BEFORE RECORDING TURNS

BOLTS MARKED (S) TIGHTENED THROUGH A 3" SLAB, ALL OTHERS TIGHTENED THROUGH PLATE PLIES.

TABLE 3

TURNS OF THE NUT REQUIRED TO BREAK BOLTS OR STRIP THREADS.

BOLT MARK	SIZE AND LENGTH	TURNS OF THE NUT: WITH TORQUE WRENCH		WITH IMPACT WRENCH		
		BREAK	STRIP	BREAK	STRIP	WRENCH USED
40E	$\frac{5}{8}\phi \times 2\frac{1}{2}$				2	F
41E					$2\frac{3}{4}$	F
56E			3			
57E	$\frac{5}{8}\phi \times 4\frac{1}{2}$	$2\frac{5}{8}$				
58E					2	D
29E		$2\frac{7}{8}$				
30E		$2\frac{1}{2}$				
31E				$2\frac{3}{8}$		E
32E				$2\frac{3}{4}$		E
35E				$2\frac{7}{8}$		F
36E					$2\frac{3}{4}$	F
155G		$2\frac{3}{4}$				
156G		$2\frac{3}{8}$				
157G		$2\frac{1}{4}$				
158G	$\frac{3}{4}\phi \times 2\frac{1}{2}$	$2\frac{1}{2}$				
139G					$2\frac{1}{2}$	C
141G				$2\frac{1}{2}$		C
142G				3		C
143G				3		C
144G				3		C
43G				$3\frac{1}{2}$		A
44G				3		A
45G				$3\frac{1}{2}$		A
33G				$3\frac{1}{2}$		C
48E		3				
65G					$2\frac{1}{2}$	C
3G	$\frac{3}{4}\phi \times 4\frac{1}{2}$	$2\frac{3}{4}$				
167G		$2\frac{1}{2}$				
168G		Ⓢ $2\frac{1}{4}$				
169G		$2\frac{1}{8}$ Ⓢ				
152G		$2\frac{7}{16}$				
153G		$2\frac{1}{4}$				
51G	$\frac{7}{8}\phi \times 2\frac{1}{2}$				$2\frac{1}{2}$	A
159G		$3\frac{1}{4}$				
160G			3			
161G		$3\frac{1}{8}$				
53G					2	A
54G					$1\frac{3}{4}$	A
56G					$2\frac{1}{2}$	A
69G					$1\frac{1}{2}$ Ⓢ	A
70G					Ⓢ $1\frac{1}{2}$	A
162G	$\frac{7}{8}\phi \times 4\frac{1}{2}$		3			
163G			$2\frac{1}{2}$			
165G			2			
166G			$2\frac{1}{2}$			
170G			Ⓢ $2\frac{1}{2}$			
172G		$2\frac{5}{8}$ Ⓢ				
135G					2	A
229G		2				
230G			$2\frac{1}{4}$			
186G					2	B
187G					$2\frac{1}{2}$	B
188G	$1\phi \times 2\frac{1}{2}$				2	B
189G					2	B
190G					$2\frac{1}{2}$	B
225G		2				
227G			$2\frac{1}{4}$			
228G			$2\frac{1}{4}$			
232G			3			
233G			$2\frac{3}{4}$			
234G	$1\phi \times 4\frac{1}{2}$		2			
235G		$2\frac{5}{8}$				
197G					$2\frac{1}{2}$	B
216G					2 Ⓢ	B
208G					$2\frac{1}{2}$	B
248G	$1\phi \times 6\frac{1}{2}$		2			
249G			$2\frac{1}{8}$			
243G			$1\frac{3}{4}$			
244G	$1\frac{1}{8}\phi \times 2\frac{1}{2}$		2			
246G			$2\frac{1}{4}$			
247G			2			
221G					$2\frac{1}{2}$ Ⓢ	B
240G	$1\frac{1}{8}\phi \times 4\frac{1}{2}$		$2\frac{1}{8}$			
242G			$2\frac{1}{2}$			
236G			$3\frac{1}{4}$			
237G	$1\frac{1}{8}\phi \times 6\frac{1}{2}$		$2\frac{1}{2}$			
238G			$2\frac{1}{2}$			
239G			$2\frac{1}{2}$			

NOTES: ALL NUTS "FINGER TIGHT" BEFORE RECORDING TURNS.
BOLTS MARKED Ⓢ TIGHTENED THROUGH A 3" SLAB, ALL OTHERS TIGHTENED THROUGH PLATE PLIES

TABLE 4

REDUCTION OF BOLT DIAMETER AFTER ONE FULL TURN OF NUT

BOLT MARK	SIZE AND LENGTH	AVERAGE DIAMETER* BEFORE TIGHTENING	AVERAGE DIAMETER* AFTER ONE TURN	DIFFERENCE IN INCHES	PERCENT REDUCTION
38E	$\frac{5}{8}\phi \times 2\frac{1}{2}$	0 616 IN	0 611 IN	0 005	0 81
39E		0 616	0 608	0.008	1.30
34E	$\frac{3}{4}\phi \times 2\frac{1}{2}$	0 746	0.737	0 009	1 47
156G		0 741	0 723	0 018	2 43
157G		0 745	0 729	0 016	2 15
167G	$\frac{3}{4}\phi \times 4\frac{1}{2}$	0 749	0 728	0 021	2 82
160G	$\frac{7}{8}\phi \times 2\frac{1}{2}$	0 862	0 845	0 017	1 97
161G		0 861	0 852	0 009	1 04
1E	$\frac{7}{8}\phi \times 4\frac{1}{2}$	0 856	0 854	0 002	0 23
163G		0 858	0 849	0 009	1 05
166G		0 861	0 859	0 002	0 23
170G		0 857	0 854	0 003	0 35
171G		0 856	0 849	0 007	0.82
228G	$1\phi \times 2\frac{1}{2}$	0 996	0 972	0 024	2 41
229G		0 995	0 965	0 030	3 02
230G		0 996	0.978	0.018	1.81
234G	$1\phi \times 4\frac{1}{2}$	0 983	0 976	0 007	0 71
235G		0 985	0 978	0.007	0 71
215G	$1\phi \times 6\frac{1}{2}$	1 014	1 011	0 003	0.30
249G		0 991	0 986	0.005	0 51
244G	$1\frac{1}{8}\phi \times 2\frac{1}{2}$	1 105	1 086	0 019	1 72
246G		1 109	1 094	0 015	1 36
241G	$1\frac{1}{8}\phi \times 4\frac{1}{2}$	1 098	1 093	0 005	0 46
242G		1 102 IN	1 097 IN	0 005	0 50

* AVERAGE OF TWO DIAMETERS, 90° APART

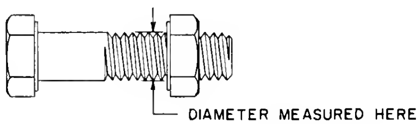


TABLE 5

TORQUE-TENSION RELATIONSHIP FOR MINIMUM BOLT TENSION

BOLT MARK	SIZE AND LENGTH	TORQUE IN FT LB	BOLT TENSION IN LB	
			RECORDED*	SPECIFIED
1G	$\frac{3}{4}\phi \times 4\frac{1}{2}$	330	27,000	25,600
2G		320	29,000	
5G		320	29,000	
6G	$\frac{7}{8}\phi \times 4\frac{1}{2}$	470	34,000	32,400
7G		470	33,000	
76G	$1\phi \times 4\frac{1}{2}$	710	37,500	42,500
77G		710	37,500	
78G		710	37,000	
79G	$1\phi \times 6\frac{1}{2}$	710	33,000	42,500
80G		710	41,000	
81G		710	34,000	
82G		710	42,000	

* DETERMINED FROM HYDRAULIC CALIBRATION DEVICE

Part 3

Specifications for Assembly of Structural Joints Using High Tensile Steel Bolts in Steel Railway Bridges

The present Specifications for Assembly of Structural Joints Using High Tensile Steel Bolts in Steel Railway Bridges (Manual pages 15–M–27 to 15–M–29, incl.) were only adopted in 1953; however, the technical knowledge gained from the large amount of research on this new type of fastener and the practical knowledge obtained from the installation of millions of the bolts in actual structures have made desirable extensive revision of these specifications. Some of the more important revisions have to do with the identification of the bolts by three radial lines on the head; the use of beveled washers only when the bearing faces under the hardened washers are out of parallel by more than 5 percent; the inclusion of recommended bolt tension values for calibrating impact wrenches; and a change in the inspection requirements.

The new revised specifications, which are offered for adoption and inclusion in the Manual, are as follows:

SPECIFICATIONS FOR ASSEMBLY OF STRUCTURAL JOINTS USING HIGH-STRENGTH STEEL BOLTS IN STEEL RAILWAY BRIDGES

A. SCOPE

1. General

a. This specification, when required by the plans, covers recommended practice for the fabrication of structural steel forming rigid joints using high-strength steel bolts tightened to a high tension. The bolts are used in holes of larger diameter than the nominal bolt size.

b. Unless otherwise specified, and until other safe rules for the design of bolted joints can be developed, the principles and rules for design of these joints and structures incorporating them shall be as required for riveted construction using ASTM A–141 rivet steel.

c. Construction shall conform to existing codes for riveted structures except as provided herein.

B. BOLTS, NUTS AND WASHERS

1. Material

a. Bolt, nut and washer material shall conform to requirements of the current ASTM Specifications, designation A 325. Bolts manufactured to these specifications are identified by marking on the top of the head with three radial lines.

2. Bolt Dimensions

a. Bolt dimensions shall conform to the current requirements for Regular Semi-finished Hexagon Head Bolts of the American Standards Association (ASA designation B 18.2).

b. In determining bolt lengths, the grip shall be calculated the same as for a riveted joint, and the values shown in Table 1 shall be added thereto. If other than the preferred thickness of circular washer (see Table 2) is used, the necessary length shall be adjusted accordingly. The total length shall be adjusted to the next ¼-in increment up to 5-in length, and to the next longer ½-in increment for lengths over 5 in.

c. Unless otherwise required, minimum thread length (extreme point to last complete thread) shall be twice the diameter plus ¼ in for lengths up to and including 6 in, and twice the diameter plus ½ in for lengths over 6 in.

Bolts too short for the formula length shall be threaded as close to the head as practical.

3. Nut Dimensions

a. Nut dimensions shall conform to current ASA requirements for Heavy Hexagon Semi-finished Nuts (ASA designation B 18.2).

4. Washer Dimensions

a. Circular washers shall be flat and smooth, and their dimensions shall be not less than would conform to current ASA requirements for Heavy Plain Washers (carburized), (ASA designation B 27.2). These dimensions are shown in Table 2.

b. Where clearance makes it necessary, washers may be clipped on one side at a point not closer than seven-eighth of the bolt diameter from the center of the washer. Where bearing faces under hardened washers of bolted parts have a slope of more than 1:20 with respect to a plane normal to the bolt axis, smooth beveled washers shall be used to compensate for the lack of parallelism.

c. All washers adjacent to the bolt head and nut shall be hardened in accordance with the requirements of ASTM designation A 325.

C. BOLTED PARTS

1. Material

a. This specification contemplates that the bolted parts shall consist of metals permitted by the AREA specifications for iron and steel structures.

2. Dimensions

a. Surfaces of bolted parts in contact with the bolt head and nut shall be parallel; except that they may have a slope of not more than 1:20 with respect to a plane normal to the bolt axis if the requirements of Sec. D, Art. 1, Par. a are observed. Bolted parts shall fit solidly together when assembled and without interposition of gaskets or other flexible material. Holes may be punched, subpunched and reamed, or drilled as required by the applicable specifications, and shall be of a diameter not more than $\frac{1}{16}$ in. in excess of the nominal bolt diameter.

3. Finish

a. The contact surfaces, when assembled, shall be bare, either descaled or carrying the normal mill scale. Contact surfaces shall be free of paint, lacquer, dirt, oil, scale, burrs, pits and other defects that would prevent solid seating of the parts or would interfere with the development of friction between the parts.

D. ASSEMBLY

1. General

a. Bolts shall be assembled with a hardened washer under the bolt head and nut as described in Sec. B, Arts. 1, Par. a and 4, Par. a. Flat washers may be used if the surfaces adjacent to the bolt head and nut do not have a slope of more than 1:20 with respect to a plane normal to the bolt axis; provided that, in all cases of non-parallel surfaces, the nut shall be torqued against a non-sloping surface.

b. All nuts shall be tightened to give not less than the required minimum bolt tension values given in Table 3 on completion of the joint.

2. Use of Wrenches

a. Wrenches shall be set to induce the Recommended Bolt Tension for Calibrating Wrenches as given in Table 3.

b. In using a manual torque wrench, the required torque can be read from the wrench dial, or in other types of wrench the torque may be indicated by a "release" of the wrench. Care should be taken that the wrench is properly calibrated. Nuts shall be in motion when torque is measured.

E. INSPECTION

1. Field Inspection

a. The inspector shall approve the procedure for calibration of wrenches and installation of bolts. The inspector shall further observe the field installation to determine that these procedures are followed. Where further inspection is required by the engineer, he shall specify in advance the method the inspector is to follow.

TABLE 1—BOLT LENGTHS

Bolt Size, Inches	*Add to Grip, Inches*
½	1
⅝	1⅛
¾	1¼
⅞	1½
1	1⅝
1⅛	1¾
1¼	1⅞

This compensates for thickness of nut, two flat washers and bolt point.

TABLE 2—WASHER DIMENSIONS

Bolt Size, Inches	*Circular Washers*			*Square Beveled Washers for American Standard Beams and Channels*		
	Inside Diameter	*Outside Diameter*	*Thickness, Gage No.*	*Width*	*Mean Thickness*	*Slope*
½	9/16	1⅜	12	1¾	5/16	1:6
⅝	11/16	1¾	10	1¾	5/16	1:6
¾	13/16	2	9	1¾	5/16	1:6
⅞	15/16	2¼	8	1¾	5/16	1:6
1	1 1/16	2½	8	1¾	5/16	1:6
1⅛	1¼	2¾	8	2¼	5/16	1:6
1¼	1⅜	3	8	2¼	5/16	1:6

TABLE 3—BOLT TENSION AND TORQUE VALUES

Bolt Size, Inches	*Recommended Bolt Tension for Calibarting Wrenches, Pounds**	*Required Minimum Bolt Tension, Pounds***	*Approximate Equivalent Torque for Required Minimum Bolt Tension, Foot-Pounds****
½	12,500	10,850	90
⅝	20,000	17,250	180
¾	29,000	25,600	320
⅞	37,000	32,400	470
1	49,000	42,500	710
1⅛	58,000	50,800	960
1¼	74,000	64,500	1,350

*Approximately 15 percent in excess of the Required Minimum Bolt Tension.

**Equal to 90 percent of the minimum Proof Load of Bolt (ASTM A 325). There is no recommended bolt tension.

***Equal to 0.0167 ft-lb per inch bolt diameter per pound tension for non-lubricated bolts and nuts. Values given are experimental approximations. If torque rather than tension is to be measured, the torque–tension ration shall be determined by the actual conditions of the application.

Report of Committee 7—Wood Bridges and Trestles

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Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   Progress in study, but no report.

2. Grading rules and classification of lumber for railway uses; specifications for structural timber, collaborating with other organizations interested.

   Progress in study, but no report.

3. Specifications for design of wood bridges and trestles.

   Progress in study, but no report.

4. Methods of fireproofing wood bridges and trestles, including fire-retardant paints, collaborating with Committee 17 and with the Fire Protection and Insurance Section, AAR.

   Progress report, presented as information .... page 636

5. Specifications for structural glued laminated lumber, collaborating with Committee 6.

   Final report, including specifications submitted for adoption .... page 641

6. Design of timber-concrete composite decks, collaborating with Committee 8.

   Progress report, presented as information .... page 641

7. Means of conserving labor and materials, including the adaptation of substitute noncritical materials, and specifications for the reclamation of released materials, tools, and equipment, collaborating with Committee 3–A, General Reclamation, Purchases and Stores Division, AAR.

No report.

THE COMMITTEE ON WOOD BRIDGES AND TRESTLES,
W. C. HOWE, *Chairman.*

AREA Bulletin 520, January 1955.

Report on Assignment 4

Methods of Fireproofing Wood Bridges and Trestles, Including Fire Retardant Paints

Collaborating with Committee 17 and with the Fire Protection and Insurance Section, AAR

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Your committee presented an advance report in Bulletin 510, September–October 1953, beginning on page 135 (Proceedings, Vol. 55, 1954, same pages), which included description and results of a series of tests designed to evaluate the protective features of fire-retardant coatings applied to treated structural timbers. These tests were conducted by the Atchison, Topeka & Santa Fe Railway under the general direction of T. A. Blair, chief engineer system, with the AAR research staff cooperating in making temperature measurements and preparing the report. Your committee is also collaborating with the AAR in connection with research work on fire-retardant coatings now under way at the AAR Central Research Laboratory. A progress report on the work done during 1953 was presented in Bulletin 513, January 1954, pages 567 and 568 (Proceedings, Vol. 55, 1954, same pages). The following report concerns progress on this research during 1954.

INTRODUCTION

The subject of fires and the losses incident to fires is both complicated and large. The Fire Protection and Insurance Section of the AAR, by questionnaire, conducts an annual survey of the nature and cost of fires sustained by AAR member roads. However, despite the many classes of fires listed, the information submitted often has been incomplete and open to question. The feasibility of totalling the dollar loss suffered by a railroad from a bridge fire represents an effort beyond the range of those involved in gathering such statistics. It is known from individual cases that a particular bridge, destroyed by fire, required some $195,000 to reconstruct. The total loss due to inconvenience, re-routing, delay in icing of lading, etc., resulted in costs approximating $2,000,000. The interruption of main line operation on one large railroad is likely to cost from $500 to $750 per min. Such data place in proper perspective the true magnitude of timber bridge fires. In view of these facts it becomes evident that an extremely thorough investigation must be made concerning the nature of treated timber bridge fires and the means whereby adequate protection may be effected.

FIELD INVESTIGATIONS

Toward this end chemical, electrical, and bridge laboratory personnel of the AAR attended and participated in field tests conducted by the Atchison, Topeka and Santa Fe Railway System over the period 1952–1954. These tests consisted in the main of constructing full-scale replicas of end and interior panels of ballasted-deck pile trestles and painting them with commercially available fire-retardant coatings previously evaluated. Thermocouples were placed at strategic locations on these structures by AAR personnel to enable recording the temperatures reached in tumbleweed fires (AREA Bulletin 510, page 135, Proceedings, Vol. 55, 1954.) The data revealed that burning tumbleweed around a single exposed pile develops temperatures in the range of 1200 to 1500 deg F. In the replica panels constructed of southern yellow pine and treated with a mixture of approximately equal parts of creosote and petroleum, temperatures approaching 1900 deg F were reached in a matter of 60 to 90 sec.

LABORATORY INVESTIGATIONS

1. Evaluation of Standard Burners and Tests

With the knowledge that flash fires of high temperature and relatively short duration (up to 5 min) represented for the most part the typical tumbleweed fire, it became possible to define the necessary conditions a laboratory instrument had to reproduce. Preliminary experiments were designed to facilitate the selection of a commercially available gas burner capable of reproducing the desired conditions. Seven such burners were examined under a variety of conditions and found unsatisfactory. A number of standard tests developed and used by such groups as the Federation of Paint and Varnish Production Clubs, the pulp and paper industry, the National Paint, Varnish and Lacquer Association, and the Forest Products Laboratory were studied and found inadequate. It became evident that a burner would have to be developed to simulate the unusual conditions of a brush and weed fire.

2. Burner and Cabinet Design

Through a systematic program some 35 burners were designed, constructed and tested. Information was accumulated relating the elements of pipe size, gas orifice diameter, burner length and burner material before an adequate experimental model was built. Eight cabinets of various dimensions and materials were constructed to house the many burners built before a choice was made. Since that time three fundamental alterations in burner design have been effected.

3. Fuel Selection

The gas used for fueling the test fires was supplied locally as natural gas (1000 Btu). However, during the winter months excessive consumer demand often reduced the gas pressure, so the local gas company injected manufactured gas (500 Btu) into the lines to maintain pressure. The use of such a mixed fuel led to variations in results and its use was discontinued. To overcome this variation in fuel of varying heat content, LPG gas or liquid propane, available in small tanks, was utilized. This gas was selected because of its general availability throughout the country. It has a heat content of approximately 2200 Btu and develops flame temperatures between 1700 and 1800 deg F.

DISCUSSION OF PROBLEM

1. Examination of Commercially Available Products

Having tentatively standardized on a burner and fuel supply, it became possible to commence evaluating protective coating materials. A comprehensive survey of the market revealed only a limited number of products. Some 40 materials, for which claims of fire-retarding properties were made, have been examined in the fire test cabinet over the past two years. Of them, several potentially useful compositions have been discovered. and the manufacturers are known to be continuing work toward upgrading them. Promising materials, when found, are exposed to atmospheric weathering on the laboratory roof and to artificial accelerated weathering in an Atlas Model XW Weatherometer. After a suitable period in each environment the aged test specimens are burned to compare their protective features with a freshly coated specimen. All tests to date have been conducted on southern yellow pine (S4S, 1⅝ by 5⅝ by 18 in) treated with a 60:40 mixture of creosote and coal tar.

2. Publicizing the Problem

Because of a scarcity of useful materials, efforts have been made at publicizing the problem and bringing its attractive market potential to the attention of the chemical and paint industries. Accounts of the problem and tentative specifications have been described in Chemical Week and Coatings, as well as having been discussed before members of the Federation of Paint and Varnish Production Clubs. Despite this publicity, few, if any, large companies have entered the field. The reluctance of industry to attack the problem of formulating a fire-retardant coating was found due to an absence of reliable information concerning the behavior of treated timber under the influence of high temperatures.

3. Exploratory Laboratory Investigations

Preliminary investigations were undertaken to learn the magnitude of temperatures developed at various depths below the surface of timber treated with different preservatives, when exposed to a flame of high and relatively constant temperature. Unexpected differences were obtained from wood treated with different preservatives. In addition, wood treated with the same preservative at different levels of retention yielded results of considerable significance. The table below illustrates some temperatures recorded in treated timber after 5 min exposure to a flame of constant heat content.

BELOW SURFACE TEMPERATURES RECORDED IN BARE TREATED TIMBER IN FIRE TEST CABINET

Treatment	*Thermocouple Location*		
	⅛ In Below Surface	*¼ In Below Surface*	*½ In Below Surface*
Creosote 16 lb per cu ft	510°F	350°F	200°F
45% Creosote: 55% Petroleum 9 lb per cu ft	1195°F	530°F	260°F

The tubercles shown in increasing quantity in the examples in Fig. 1 illustrate the product of incomplete combustion of bleeding preservative. The significant fact is that these tubercles are extremely hard and capable of destroying a paint bond. What is even

Retentions 23 lb/cu ft 25 lb/cu ft 30 lb/cu ft 36 lb/cu ft

Fig. 1—Examples of specimens of southern yellow pine treated with a 60:40 mixture of creosote and coal tar after five minutes exposure in fire test chamber.

more important is the amount of carbonized material developed relative to the respective retentions. It becomes evident that investigators working with the same timber but unknowingly with different retentions could arrive at different and disputable conclusions. These data were significantly important in that they called attention to a number of little appreciated facts. In the first case, timber is heterogeneous and does not absorb throughout its length the same amount of preservative during treatment. Secondly, timber specimens when given a so-called 10-lb treatment may vary in absorption from 5 to 20 lb per cu ft. Thus, the sample selected for testing becomes the crucial variable. In addition, timber which is treated by the full-cell method will yield results different from timber treated by the empty-cell Lowry and Rueping methods. The various preservative mixtures of creosote, creosote and coal tar, and creosote with petroleum, provide additional variables of significance.

Appreciation of these conditions led to a survey of each volume of the AREA and AWPA Journals from the start of publication to the present for data from every report printed concerning the various species of timber used and treatments given to cross ties and bridge timbers. It was concluded from these studies that the bulk of timber used during the last 50 years is Douglas fir and southern yellow pine. The popular treatments have been creosote; 60:40 creosote–coal tar; and 50:50 creosote–petroleum.

In order to learn the behavior of such preserved timber under the influence of fire, arrangements were made to treat, under controlled conditions, specimens of both species with each of the three preservatives at a number of retentions.

4. Present Work

A contract was entered into with the U. S. Department of Agriculture, Forest Products Laboratory, to treat in their experimental cylinder 659 specimens of timber. Some 439 pieces of B or better, S4S, southern yellow pine, and 220 pieces of B or better, S4S, Douglas fir were impregnated. Prior to treatment each piece of pine was stained on its edges with benzidine–nitrite, and each piece of fir was stained similarily with ferric chloride. These stains developed contrasting colors, enabling one to estimate the location and percent of sapwood and heartwood respectively.

Specimens were stored at 85 percent relative humidity and 35 deg F until ready for treatment. Impregnation took place in a pilot tank measuring 18 in. in diameter and 48 in. in length and capable of holding 30 pieces of timber. The specimens were assayed for moisture content and weighed prior to placement in the tank and again weighed immediately upon removal from the tank following treatment.

The pine was treated full cell to secure a retention of 30 to 40 lb per cu ft of preservative. The fir was treated similarly, but took up smaller quantities of oil (in the range of 25 to 30 lb per cu ft). Pilot runs of 10 specimens were used to determine optimum treating conditions for the low retentions. Pine was treated then by the empty-cell process to obtain retentions of 20 and 10 lb per cu ft, respectively. Fir was treated in similar fashion to yield retentions in the range of 10 to 12 lb per cu ft.

Enough specimens have been obtained in each instance to afford an opportunity for developing useful information from timbers whose absorption of oil varies somewhat above and below specified retentions. It is intended to conduct temperature studies similar to those reported earlier on the two species of wood impregnated with each of the three preservatives in the full and empty-cell processes. In addition, promising coating materials will be applied to each of the specific types of treated wood and evaluated in similar fashion.

It is expected that these studies will disclose significant characteristics peculiar to the various treatments and will call attention to considerations important to those desiring to protect a structure from fire. The information derived from these investigations will be made available in appropriate publications, enabling paint formulators to concentrate their efforts in channels leading to an early development of satisfactory fire-retardant coating materials.

Report on Assignment 5

Specifications for Structural Glued Laminated Lumber

Collaborating with Committee 6

F. E. Schneider (chairman, subcommittee), R. D. Culbertson, J. T. Evans, E. L. Haberle, F. J. Hanrahan, M. W. Jackson, R. E. Jacobus, C. S. Johnson, L. P. Keith, J. R. Kelly, J. C. Korte, T. K. May, J. M. Montz, W. A. Oliver, A. H. Schmidt, R. L. Stevens, F. L. Thompson, L. W. Watson.

Last year your committee presented, as information, a draft of Specifications for Structural Glued Laminated Lumber together with an appendix and tables (Bulletin, January 1954, pages 568 to 582, incl., and Proceedings, Vol. 55, 1954, same pages), and requested comments and criticisms thereon.

The following revisions of these specifications, affecting only Arts. 1a and 11c, have been recommended and approved by the committee:

1. General
   a. Structural glued laminated lumber is any stress-rated member comprising an assembly of properly selected and prepared wood laminations in which the grain of all laminations is approximately parallel longitudinally, and in which the laminations are securely bonded with approved adhesives.

11. Finished Sizes
   c. Members that are specified to be pressure impregnated with a preservative shall be finished to size and all cutting, framing, and boring of timbers shall be done before treatment unless otherwise specified.

These specifications, with above revisions, are now submitted with the recommendation that they be adopted and published in the Manual.

Report on Assignment 6

Design of Timber–Concrete Composite Decks

Collaborating with Committee 8

W. A. Oliver (chairman, subcommittee), J. C. Boston, E. M. Cummings, C. S. Johnson, C. S. Johnson, Jr., W. D. Keeney, J. C. Korte, T. K. May, W. H. O'Brien, O. C. Rabbitt, H. S. Rimmington, A. L. Schmidt, B. J. Shadrake, Josef Sorkin.

This is a progress report, submitted as information.

T. K. May, director of technical service, West Coast Lumbermen's Association, has compiled the following report which your committee believes is an excellent resumé of available data on the subject to date.

Composite Timber–Concrete Construction

By T. K. May

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Composite construction is defined for purposes of this report as a combination of different structural materials in a manner that utilizes the preferred strength property of each material, and as though the whole were homogeneous when stressed in flexure. Essentially, the development of a composite section depends on an efficient means of providing adequate shear resistance at the juncture plane of the two materials.

The composite constructions described herein are those that combine concrete and lumber, with the concrete in compression and the wood in tension when stressed in flexure.

Greater service life with greater economy, which engineers are always striving for, has been the prime reason for the development of this kind of structural element. The concrete provides an enduring wearing surface to handle the movement of today's heavy loads and fast moving traffic. It also provides more safety from skidding for outdoor structures in wet weather with rubber-tired vehicles.

Wood for the tension portion of the cross sections of the several types of composite constructions is used for several reasons. The wood parts or members are easily fabricated prior to placement. In place, they are sufficient to support the dead load of the structure while concrete is being placed, and may be capable of supporting equipment used in construction, though the strength of the self-supporting wood parts should be checked as to capacity before this is attempted.

To date, there have been developed two basic types of composite construction with variations in methods of accomplishing the desired result. One basic type of deck consists of a concrete slab on timber stringers arranged as a series of "T" beams, a timber stringer forming the stem and the concrete slab forming the flange.

The Oregon State Highway Department, realizing that more than half of their bridge requirements are in the short span category, conducted a full research program in 1932 at Oregon State College on this type of construction as a means of building bridges of minimum first cost and having low maintenance expense and high roadability.*

Five methods of developing the horizontal shear at the juncture between the concrete flange and the timber stringer stem were investigated. Both 4-in by 14-in and 6-in by 16-in Douglas fir stringers with 6-in by 15-in and 6-in by 24-in concrete flanges, respectively, were used in the tests. The methods used to develop shear resistance are as follows:

1. Several rows of ⅜-in by 8-in spikes, depending on the stem width, were driven over half their length into and along the top edge of a stringer, the projecting portion thus being embedded in the concrete.
2. Shallow, square-ended daps were cut at intervals across the tops of the stringers, which formed matching projection in the concrete flange when it was poured.
3. A combination of daps and spikes as in methods 1 and 2.
4. Short lengths of pipe keys set into shallow holes bored along the top edge of stringers, with a portion projecting above the wood over which the concrete flange was poured.
5. Rectangular steel plates driven half their depth into slots cut transversely across the top of the stringers, the other half projecting into the concrete flange when poured.

* Loading Tests on a New Composite-Type Short-Span Highway Bridge, Oregon State Highway Commission, Highway Department Technical Bulletin No. 1.

Tests of these five arrangements gave results from the strongest to the weakest in the following order:

1. Pipe keys.
2. Daps in stringer tops plus spikes.
3. Spikes only.
4. Plates in slots across stringer
5. Plain daps across stringers.

The variation in average ultimate strengths between the first four methods was about 5 percent; between the fourth and fifth, about 15 percent. The large spread in ultimate values between composite beams having only square ended plain daps (No. 5) and beams similarly dapped but with the addition of spikes (No. 2) may be due to the lifting out of the daps which was noted. Uplift was apparently prevented when the spikes were added. The method chosen for use in the design of bridges was the second, daps in stringers plus spikes, as being the most economical of materials and fabrication.

It is noteworthy that, characteristic of all the beams tested, the load-deflection rate was constant with no definable point of proportional limit.

In addition to the usual tests to destruction, several beams were subjected to repeated loadings and two beams were investigated for the effect of temperature variation. The alternated loading tests showed that there is no appreciable loss in strength. Some residual deflection was noted between loading cycles, but the amount of set gradually decreased towards zero, indicating plastic flow of the materials.

The temperature tests are most interesting. They are the only tests with composite constructions that have been made and the results are applicable to any composite constructions of lumber and concrete. Three freezing and thawing cycles were made with 2 beams, from 15 to 69 deg F, a range of 54 deg, which will very rarely obtain under actual service conditions. Careful strain gage measurements revealed that with a change in temperature, the top of the concrete flange, which would be the roadway surface if on a bridge, changed dimension in a nearly normal manner, that the bottom surface of the slab changed somewhat less, and that the bottom of the timber stem changed dimension in a manner not normal to wood Such a reaction to temperature change would be expected as there is a definite thermal coefficient of expansion for concrete, whereas for wood, this coefficient of expansion is, for all practical purposes, nil. Hypothesis and test results indicate that for these reasons the timber stem restrains the concrete flange from responding to normal dimensional changes at the juncture of the two materials and secondary stresses are induced. As temperature drops below the mean, the secondary stresses at extreme fiber are a reversal from those stresses induced by usual positive moments. When temperatures rise above the mean, secondary stresses at extreme fiber will be like, and hence additive, to stresses induced by positive moment. Analysis of these secondary temperature bending stresses shows that they are not large, and the investigation recommends that they are not sufficient to cause serious concern in designing.

On the other hand, whether the temperature change rises or falls from the mean, the restraint at the juncture of the two materials develops secondary shearing stresses that are additive to those from normal bending, and hence must be considered in designing shear keys.

As the thermal expansion coefficient for wood is practically zero, the dimensional change in concrete is all that induces stress at the shear juncture. Hence, design of the shear connection as required for temperature only is as follows:

$$n = \frac{A_c\, 2f_c}{s}$$

n = number of shear connections required for temperature stress.
A_c = area of concrete flange considered to be involved by restraining timber stem.
f_c = unit stress in concrete induced by temperature change within the range selected.
s = the value of each shear connector.

At the time the research project was being conducted, one of the flange limitations was a width not more than six times the width of the stem. This limitation has been modified to four times the width of the stem in current recommendations.

Stress analysis involves two phases: The determination of extreme fiber stress due to bending; and the shearing stresses at the junction point of the two materials with proper connection details. If it is assumed that the junction connection is adequate, is without inelastic deformation, and has elastic characteristics in keeping with the materials of the beam, then the beam may be designed by transforming the composite section into an equivalent homogeneous section in the ordinary manner. The procedure is to multiply the flange width by the ratio of the modulus of elasticity of concrete to the modulus of elasticity for the species of timber used, $\frac{E_c}{E_t}$, and thereafter design will be as though the transformed dimensions are for a homogeneous timber beam.

Having established a design criteria, the State of Oregon, in 1932, began the construction of composite "T" beam bridges, and has completed 198 of these structures throughout the state highway system. The total lineal footage to date is 23,340. The length of spans is quite varied as there is 1 bridge of 1 span at 10 ft, another of 54 spans at 29 ft, and another, which has since been removed, of 6 spans at 40 ft. This latter structure had wood stringers measuring 12 in by 30 in. It was found that as these stringers seasoned, which would require many years to reach moisture equilibrium, they gradually twisted, probably due to the presence of sloping or spiral grain. After 19 years this bridge was removed to make way for a reservoir. All of the other bridges are giving excellent service. This leads to a conclusion that for this type of construction, glued laminated stringers should be used when the required stringer size becomes very large.

The second basic type of composite construction consists of a continuous wood–concrete slab across the width of the structure. Many slab decks of composite timber–concrete construction have been built throughout North America. They are used for bridges, wharves, docks and buildings. Testing on the first of these types was conducted in 1933 by the American Wood-Preservers' Association at George Washington University.* Additional tests were subsequently made by the State Roads Commission of Maryland on a completed bridge having a 67 deg skew** and at the University of Illinois.*** The second and latest type was developed by the West Coast Lumbermen's Association in 1948, which is similar to that developed by the American Wood-Preservers' Association. The latter design aims at further economies by a reduction in the hardware and labor required.

Both the current type of composite timber–concrete slabs use a laminated wood deck as the base or form for the concrete surface and for the tension portion of the com-

* New Type of Composite Beam and Design of Composite Slab Highway Deck. J. F. Seiler, Wood Preserving News—Nov., Dec., 1933.

** Treated Timber in Heavy-Duty Composite Highway Bridges. W. C. Hopkins, American Wood-Preservers' Association—1939.

*** Tests of Composite Timber and Concrete Beams. Frank E. Richart and Clarence B. Williams, Jr., University of Illinois, Bulletin Vol. 40, No. 38—May 1943.

posite section, the concrete acting in compression. The essential difference between the two deck designs is in the method of developing the shear at the juncture between the two materials. Hence, design for fiber stress due to bending is the same for both, design difference being the details and values used in developing the shear resistance.

All the laminated slab decks are made of dimension lumber with the wide face vertical and with the top of alternate laminations 2 in higher than the next adjacent piece. This may be accomplished in two ways: half of the laminations used will be 2 in wider than the other half, or each alternate lamination will be staggered 2 in above its adjacent piece.

The choice of laminating with alternate widths or of the same width will depend on the amount of wood depth required by the span or the load.

A metal "shear developer"* was the first method investigated for development of shear resistance in composite decks. These devices are triangular steel plates driven into precut slots at intervals along the channels between adjacent laminations.

In the initial tests, the shear developers were set at an angle of about 10 deg from the vertical in order to provide resistance against uplift. Present practice is to set the shear developers vertically and drive 60d spikes on 24-in centers, at an angle facing away from the center of span, along the top edge of each upstanding lamination. Spiral dowels may be substituted for the uplift spikes, in which case the dowels are driven vertically.

Tests were made to establish the shear value of a shear developer and the efficiency of the composite section as a beam. The conclusion reached was that efficiencies approximating 100 percent can be obtained.

The tests made at the University of Illinois covered several possible methods for developing the shear at the junction of the two materials. These included beams with the shear developers set at an angle of 15 deg from the vertical, shear developers placed vertically, and shear developers placed with 60d uplift spikes both placed vertically. Also tested were boat spikes and lag screws set part way into the upper edges of all laminations. They were tried vertically and at an angle of 45 deg. A saw-tooth pattern was also cut in those alternate laminations at the bottom of the channel between laminations for a set of tests with and without 60d uplift spikes set vertically. The bottom of the saw-tooth gullet was cut 1 in deep and "teeth" were spaced 8 in on centers.

Bending tests of these several beams were compared with a control beam that had no shear connection between the two materials other than natural friction. The following comparative table gives some idea of the efficiency of the various shear connection methods investigated.

Shear Connection	*Average Strength Ratio at Ultimate*
None	1.00
R. R. spikes, vertical	1.535
Shear developers (¼″ Pl.) and 60d spikes	1.50
Shear developers (⅜″ Pl.) and 60d spikes	1.48
⅝″ x 8″ Lag screws set at 45 deg	1.435
Shear developers (¼″ Pl.) and 60d spikes	1.38
Shear developers (12 Ga.)	1.38
Shear developers (12 Ga.) and 60 spikes. Repetitive loading	1.365
Shear developers (⅜″ Pl.)	1.35
"Saw-tooth" daps and 60d spikes	1.26
Shear developers (¼″ Pl.)	1.25
R. R. Spikes at 45 deg	1.245
⅝″ x 6″ Lag screws, vertical	1.24
"Saw-tooth" daps	1.04
Shear developers (¼″ Pl.)	1.005

* Patent rights owned by the American Wood-Preservers' Association.

The preceding comparison can be misleading unless it is known that the shear connections used were at spacings chosen with the intention of producing approximately equal horizontal shearing strengths. They do not represent the relative effectiveness of the individual units.

Furthermore, most of the beams failed otherwise than in the shear connection. Some failed by compression in the concrete and some failed by tension in laminations. With normal variability of materials, such variability of failure would be expected in a well proportioned section. Horizontal shear failures in the concrete were noted in some of the beams having shear developers, at a line just above these devices. One of the beams having saw-tooth daps and no nails failed by shearing of the concrete projections moulded into the daps.

The low values for the shear developers set at 15 deg from vertical and the plain "saw-tooth" daps no doubt result from an observed tendency for the concrete to lift from the laminations as shear was developed.

The calculated bearing stress developed on the vertical face of the saw-tooth daps was 4000 lb per sq in for the University of Illinois tests, and for the "T" beam tests by the Oregon Highway Department, similar bearing for the square cut or castellated daps, as they are frequently called, ranged from 3400 to 3700 lb per sq in.

The University of Illinois tests also show that though there are two neutral axis in the composite section, the closeness of the two axis is not sufficient to warrant departure from the theory of linear distribution of stress between extreme fibers in homogeneous members. In fact, strain measurements at mid-span of the test beams showed perfect linear distribution of one of the beams with shear developers, and for the balance of the beams with these devices plus the beams with saw-tooth daps, the distribution of bending stresses was, for all practical purposes, lineal.

These elaborated references to test data for beams with shear developers and daps is given herein because these two shear connections are those currently being used in construction.

No tests have been made of the composite design developed by the West Coast Lumbermen's Association, nor does it appear necessary that tests be made, as there is ample related test data available.

Daps are used to develop shear at the juncture of the two materials in the West Coast Lumbermen's Association type slab. Of a castellated pattern, the unit shear stress in the materials is quite low because each lamination is dapped and shear resistance is developed over the total uninterrupted width of the slab. As it is known that stress concentration occurs at the apex of sharp angles, the bearing surfaces at the ends of the daps are sloped at an angle of 30 deg from the vertical to reduce the stress concentration. (See Fig. 1).

Vertical components of forces will be developed because of the slope, but this is adequately resisted by grooves milled the full length of each upstanding lamination to form a positive bond and resistance to all uplift. (See Fig. 2).

Though all tests of the methods of construction of composite slabs, as described up to this point, have for convenience been made in the form of narrow widths or beams, a transverse distribution of concentrated loads would be expected.

The most reliable tests to determine transverse distribution of highway wheel loads were made in 1939 by the State Roads Commission of Maryland*. These tests were also to check on earlier and less accurately conducted tests. The bridge selected for test use

* Treated Timber in Heavy-Duty Composite Highway Bridge, By W. C. Hopkins, 1939.

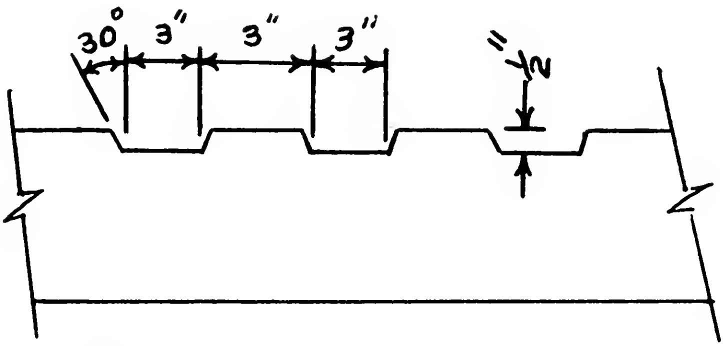

Fig. 1—Castellated daps in all laminations of the West Coast Lumbermen's Association modified composite deck slab.

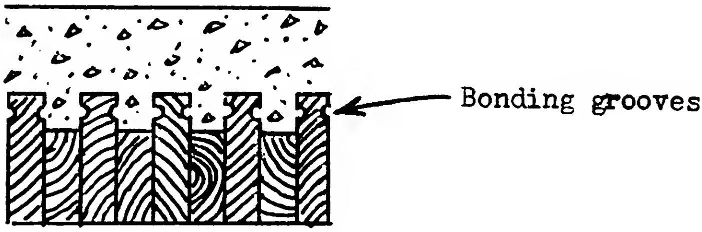

Fig. 2—Typical cross section of West Coast Lumbermen's Association composite slab, showing method of bonding to resist uplift.

has three 21-ft spans and a roadway width of 56 ft, plus two 8-ft sidewalks. With such a wide roadway, a true determination of transverse distribution from concentrated wheel loads could be determined without introducing curb action as a variable.

In these tests, a single wheel load was found to distribute over 15.1 ft for moment. By calculating the percentage of deflection caused by 4 wheels of passing vehicles at normal distances from a critical point and adding to a unit deflection assumed for the 1 wheel at the critical point, a distribution of 5.1 ft was arrived at for a single wheel load. Distribution for more than 4 wheels is not significant because of the remoteness of such wheels from any 1 critical wheel.

It has been customary to assume a somewhat narrower transverse load distribution for shear than for moment calculations, since the critical position of the load for maximum shear will be closer to the support. Tests at the Bureau of Standards gave 70 percent of the slab width for transverse distribution with the load at the quarter point, and 80 percent with the load at mid-span. Thus a distribution of 4 ft is recommended.

The analysis of the deck will depend on the method of construction, whether the wood sub-deck is used without falsework to support the total dead load during concrete placing, or whether falsework is used and the composite deck supports the total dead load after the concrete has set and the falsework struck.

Under the first condition, plastic flow of wood under load will cause a redistribution of moments for continuous slabs. Such a redistribution may be calculated approximately using test information from the Forest Products Laboratory on the relation between the calculated ratio of moments and the true (test) ratio for continuous beams at ultimate strength.

Thus, if a negative moment is computed to be 66⅔ percent of the simple span moment for an interior span of a multi-span deck, by comparing the computed positive-negative moments ratio with the test ratio, the negative moment becomes 58 percent of the simple span moment. Further redistribution of moment occurs due to interruption of laminae over the support. This reduction, based on experience on the probable number of laminations interrupted, brings the negative moment to 50 percent of the simple span moment. This is compensated by the increase in positive moment.

For a continuous composite slab, the portions subject to negative moment will have a different stiffness factor, *EI,* from that in the section under positive moment. This difference will be reflected in the moment of inertia through the usual method of reducing the section to a transformed equivalent section of one material.

Based on the supposition of a different moment of inertia for portions of a span under negative or positive moments, factors have been computed for varying ratios of these moments of inertia which, when applied to the span will give a point of inflection. As laminations are of necessity frequently spliced, the actual point of inflection will be closer to the support than for unspliced pieces. Thus, in establishing the table for positive and negative moments as a percentage of simple span moments, further adjustment factors are supplied.

The relationship of $\frac{E_c}{E_w} = 1$ and $\frac{E_c}{E_w} = 2$ are reasonable assumptions to cover a number of variable sections. Both concrete and wood have variable moduli of elasticity, depending on the dryness of the wood and the age of the concrete. The recommended value of *E* for Douglas fir and southern pine is 1,600,000. This is a green value, which increases to about 2,000,000 on drying. Seven-day old concrete has an *E* value slightly less than the green value for Douglas fir. The maximum values of *E* for both concrete and wood are not fixed and any values used in design are assumptions.

A ratio of 1 is close to actual conditions prior to final seasoning of the composite materials. After seasoning, a more realistic ratio would indicate a slightly higher stress in concrete, with a correspondingly lower stress in the wood. Prior to seasoning, the relationship of stresses is reversed, when the $\frac{E_c}{E_w}$ value is assumed to be 2, but are probably closely balanced after the materials are dry.

Tests of completed composite decks have shown an increase in stiffness and strength with age, which would indicate the assumed ratios are within conservative limits.

Furthermore, since the exact values for E_c and E_w cannot be determined prior to design, and as a more refined ratio will result in but a slight change in stresses, a further refinement is not deemed necessary.

As a very large number of composite timber–concrete slabs have been built, it is impractical to summarize the extent of such use. As the volume of construction of the three principle types is quite large, the Standard Specifications for Highway Bridges of the American Association of State Highway Officials—1953 edition, now cover the basic requirements.

Report of Committee 11—Records and Accounts

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J. L. Willcox
Louis Wolf
Committee

(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

The Committee on Records and Accounts,
H. N. Halper, *Chairman.*

AREA Bulletin 519, January 1955.

Report on Assignment 1

Revision of Manual

M. A. Bryant (chairman, subcommittee), F. B. Baldwin, P. D. Coons, D. E. Field, C. C. Haire, E. M. Killough, W. A. Krauska, W. M. Ludolph, M. F. Mannion, J. B. Mitchell, J. H. O'Brien, R. L. Samuell, W. F. Sanders, J. H. Schoonover, J. N. Smeaton.

Your committee submits the following report of progress in further revision of the AREA Manual of Recommended Practice.

The revision of Graphical Symbols, Figs. 1 to 8, incl., appearing on pages 11–4–11 to 11–4–18, incl., has been completed by a special joint committee consisting of two members of this committee and two members of Committee V of the Signal Section, AAR, operating as American Standards Association Subcommittee 1–ASA–Y–32.1.

In addition, ASA Subcommittee 1 made revisions in American Standard Graphical Symbols for Railroad Use, ASA Z32.25, coordinating all revisions with those made in AREA Graphical Symbols. Revisions were submitted to Allen F. Pomeroy, chairman, Y–32 Advisory Group, ASA, on September 20, 1954, for review of his group, and all other committees of ASA. This may take a year, but since any further revision may affect the AREA symbols under study it is recommended that revision of Figs. 1 to 8, incl., pages 11–4–11 to 11–4–18, incl., be deferred until final approval of ASA.

Report on Assignment 2

Bibliography on Subjects Pertaining to Records and Accounts

A. H. Meyers (chairman, subcommittee), M. M. Gerber, C. E. Lex, Jr., O. M. Miles, B. H. Moore, F. H. Neely, E. J. Rockefeller, J. E. Scharper, H. C. Wertenberger, W. C. Wieters, L. Wolf.

This report is submitted as information.

Your committee presents the following bibliography of subjects pertaining to railroad records and accounts for the period September 1953 to September 1954.

Depreciation

1. A British View of Depreciation Allowance—What Others Think. Public Utilities Fortnightly, Vol. LIII, No. 5, March 4, 1954, pp. 314–316.

The impact of inflation on original cost depreciation has long been the subject of lively discussion on this side of the Atlantic. A recent debate in the British Parliament indicates, however, that the problem is of equal interest in Great Britain. The question was recently debated in the House of Lords in connection with a request that the English government consider measures which would allow British ship owners to set aside adequate reserves to meet replacement costs. The discussion that followed contained some interesting comments on the whole question of original cost depreciation.

2. Re Treatment of Federal Income Taxes as Affected by Accelerated Amortization, Federal Power Commission, Opinion No. 264, Docket No. R–126, December 4, 1953. Public Utilities Fortnightly, Vol. LIII, No. 7, April 1, 1954, pp. 41–54.

Proceeding to consider rules respecting the treatment of federal income taxes for rate making where a fast tax write-off is permitted by the Internal Revenue Bureau; rules adopted.

3. Depreciation in Relation to Inflation, comments by Bowen Ely, financial editor of Public Utilities Fortnightly on an address by Finance Vice President F. Warren Brooks of the Cleveland Electric Illuminating Company, before the New York Society of Security Analysts on the topic "Economic Depreciation." Public Utilities Fortnightly, Vol. LIII, No. 9, April 29, 1954, pp. 556–559.

Mr. Ely points out in his comments that to some extent this follows the lines of Mr. Brooks' article "Needed Reform for Utility Tax Depreciation" in the Public Utilities Fortnightly of September 24, 1953. However, some new points were brought out, both in the talk and in the ensuing discussion, which may be of interest. He makes the point that unless the depreciation accruals and reserves are adjusted to meet higher plant replacement costs, net earnings are overstated and dividend pay out ratios are incorrect.

4. New Write-off Rules Will Force New Decisions. Business Week, March 13, 1954, pp. 96–98.

New tax rules to speed up the rate of capital spending write-offs seem almost certain to be passed by Congress this year. The changes are part of the omnibus tax revision put together by the House Ways and Means Committee (B.W., February 13, 1954, p. 136).

Essentially the proposal on depreciation of capital assets does two important things: it gives management the chance to recover the money it spends for plant and equipment much faster than has been the case in the last 20 years. For the first time in years top management—rather than government—would be able to make some of its own decisions on business depreciation policy for tax purposes. Up to now the Treasury Department has called the tune on methods and rates. The new bill allows much more flexibility.

The article points out how your company might have fared in the postwar boom if the proposed depreciation rules had been in effect.

5. Depreciation Reform. Steel, Vol. 133, No. 18, November 2, 1953, pp. 79–86.

The United States is hesitant about reform because it has a bear by the tail and does not know how to let go. The problem results because the current tax depreciation laws and rules are forcing industry to underdepreciate to the tune of about $6 billion a year according to estimates by Machinery and Allied Products Institute. The sum is being called "profit" by industry and taxes are being paid on it at the rate of at least 52 percent—probably more because of the excess profits levy. While government and industry men agree that reform would eventually probably increase revenue, they also agree that a liberalization—no matter how worked—would mean a marked decrease in tax receipts in the early years, even though the decrease would be made up by increased revenues later. The problem is how to weather those early years.

6. Let's Scrap our Current Depreciation Regulations, by Roger F. Waindle, president, American Society of Tool Engineers. Mill & Factory, Vol. 53, No. 6, December 1953, pp. 77–80.

We need an entirely new concept in our taxing policy on machine depreciation. For instance:

Just where do you draw the line between capital equipment and consumption tooling?

Which machines should be charged against capital and which against operating costs?

Who is the best judge of a tool's obsolescence?

Why is it frequently more economical to pay more for fixing up an old clunker than it is to buy a new and better machine?

7. Realistic Depreciation Policy. Book by George Terborgh.

Some years ago the Machinery & Allied Products Institute published a major contribution to the theory and practice of equipment policy. This work, Dynamic Equipment Policy, and its sequels, MAPI Replacement Manual and Company Procedural Manual on Equipment Analysis, have already had a profound impact on the thinking and practice of management and their influence continues to grow.

While the interest of the Institute in the related subject of depreciation policy goes back to its founding, and while it has published over the intervening years an extensive series of bulletins, pamphlets, and statements to Congressional committees on various aspects of the subject, it has not produced in this field heretofore a study comparable to Dynamic Equipment Policy. The present volume fills this gap. It is intended to be and is a worthy companion to the earlier work.

8. Taxes and Depreciation Policy, by R. C. Staebner. American Gas Association, 35, November 1953, pp. 27–28.

9. The Future of Lease Financing Under New Depreciation Rules, by Albert H. Cohen, CPA, Ph.D., staff assistant to the American Institute of Accountants' Federal Taxation Committee. The Journal of Accountancy, Vol. 98, No. 2, August 1954, pp. 189–196.

The advantages of long-term leasing over owning certain types of property will be vitally affected by the more liberal depreciation policy in the new internal revenue code.

This article is a discussion by Mr. Cohen of the effect this liberalization will have on the practice of long-term leasing and also the effect upon tax payers who entered into long-term lease contracts over the past few years in anticipation that there would be no change in tax depreciation policy.

10. How Significant Is a Computed Depreciation Reserve? by George T. Logan. Edison Electric Institute Bulletin, May 1954, pp. 163–166.

11. Conventional Depreciation Allowances versus Replacement Cost, by Robert Esiner, Controller, November 1953, pp. 513–514.

12. Another Look at Depreciation Allowances, by R. K. Mautz. Controller, January 1954, pp. 24–25 and 28.

13. Present Policy of the Internal Revenue Service on Depreciation Allowance, by H. E. Smith. NACA Bulletin 35, February 1954, pp. 789–790.

14. What Do Executives Think Depreciation Is? by Robert G. James. NACA Bulletin, Sec. 1, May 1954, pp. 1138–1147.

Rate Base

1. The Rate Base Is Here to Stay, by Francis X. Welch, managing editor, Public Utilities Fortnightly. Address delivered before the Utility Law Section of The American Bar Association at Boston, Mass., September 24, 1953. Public Utilities Fortnightly, Vol. LII, No. 9, Oct. 22, 1953, pp. 635–641.

This paper is a discussion of a subject which is so fundamental to the law of public utility regulation—the rate base and its related factors of return and depreciation; also an attempt to bring forth something new or valuable by way of conclusion or future outlook. A number of decisions by both courts and commissions are referred to with a discussion of their reasonableness under the statutory requirement that they must be just and reasonable.

2. Significant Trends as to Rate Base Depreciation and Rate of Return, by Stuart F. Kosters, assistant appraisal manager, Stone & Webster Engineering Corporation. Address delivered before the Utility Law Section of The American Bar Association at Boston, Mass., September 24, 1953. Public Utilities Fortnightly, Vol. LII, No. 9, October 22, 1953, pp. 641–650.

This address opens with a brief discussion of the "end result" principle which was adopted by the U. S. Supreme Court in the Hope Natural Gas Company decision. In his opinion the end result approach does not stand up as the conclusions stand unsupported by test.

The main part of Mr. Kosters' address covered the consideration of the three individual subjects which were assigned for discussion. The first consideration was the very important rate base. The second subject was the rate of return. Depreciation was the third and final subject for consideration. Mr. Kosters limited himself to an engineering discussion of the topics and did not indulge in legal interpretations of court or commission decisions.

3. Recent Significant Trends in Public Utility Rate Determination, by D. F. Houlihan, partner, Price Waterhouse & Company. Address delivered before the Utility Law Section of The American Bar Association at Boston, Mass., September 24, 1953. Public Utilities Fortnightly, Vol. LII, No. 9, October 22, 1953, pp. 650–660.

In his opening remarks Mr. Houlihan stresses that it is appropriate that some of the controversial factors of utility rate making be discussed from the viewpoint of several professions whose special talents are required for the attainment of equitable results. This opportunity to learn the feelings of the other fellow should help us all to coordinate our thinking since we share a common objective: the attainment of a fair balance among consumer, management and investor interests. Nothing is more in order than a coordinated approach at this time since we could be at a turning point in regulatory philosophy: the beginning of the end of a painful era of slavish adherence to the original cost accounting concept. Recent court decisions in Illinois, Maryland and Maine, and other events, are indicative of a trend toward the reintroduction of the judgement factor in rate determination.

4. U. S. Supreme Court Decisions Affecting Public Utility Depreciation, by Sidney Davidson, Ph.D., CPA, associate professor of accounting, The Johns Hopkins University. The Journal of Accountancy, Vol. 96, No. 3, September 1953, pp. 331–335.

Analysis of Supreme Court decisions takes a little wind out of the sails of the original cost devotees, for reading the language of these decisions shows that original cost, as such, does not really have the force of gospel. This article considers these decisions, and suggests some alternative methods of depreciation which conceivably could comply with court dicta and at the same time provide a little flexibility for combating the effect as it is reflected in the accounts.

5. Practicalities in Rate Making Today, by Justin R. Whiting, chairman of the board, Consumers Power Company. Public Utilities Fortnightly, Vol. LIII, No. 7, April 1, 1954, pp. 399–412.

This is an analysis of the rate-making situation as it has developed in up-to-date regulatory practice. It contains a background and a summary which point to the basic problem of modern rate regulation—keeping abreast of cost changes.

6. Revaluation of Fixed Assets, by J. Fred Weston, associate professor, University of California at Los Angeles. The Accounting Review, Vol. XXVIII, No. 4, October 1953, pp. 482–490.

The magnitude of the war and postwar changes in the general price level has aggravated difficulties of accurate and unambiguous income measurement. Wide attention has been given to the extent to which recognition should be given to changed prices of assets in the determination of a base for calculation of depreciation charges. Various methods and the difficulties involved are discussed by Mr. Weston in paper.

7. Cost: Is It a Binding Principle or Just a Means to an End? by Samuel J. Broad. The Journal of Accountancy, Vol. 97, No. 5, May 1954, pp. 582–586.

Although cost usually provides the best basis for implementing the realization concept in measuring income, departures from it may be needed for balance sheet purposes. Examples are cited to indicate in a general way that income is a concept, not something absolute, but in part at least a matter of definition or convention.

8. American Industry Is Being Taxed Into Obsolescence, by T. Berna, general manager, National Machine Tool Builders' Association. Mill & Factory, Vol. 53, No. 4, October 1953, pp. 77–82.

This paper states in part: "What the Internal Revenue Department is doing to American industry shouldn't happen to our worst enemies. By the implementation of TD–4422 and Bulletin "F", industry is practically being forced to keep and use its old obsolete tools. It can only modernize at a terrific loss and expense. These regulations should be changed right now so that industry will have an incentive and can afford to keep its plant modern."

9. Opponent of Replacement Cost Depreciation Cites Dangers, by Maurice J. Kluger, C.P.A. The Journal of Accountancy, Vol. 97, No. 3, March 1954, pp. 279–280.

In accordance with current principles, Mr. Kluger presents an alternate between "cost absorption" depreciation and "replacement cost" depreciation. As he states it: "Net profit is gross income minus cost; proponents of replacement cost depreciation wish to amend that to gross income minus costs minus additional replacement costs."

10. Replacement-Cost Depreciation—Realistic Concept of Cost Needed, by Ernest H. Weinwurm, associate professor, Industrial Engineering, Stevens Institute of Technology, letter. The Journal of Accountancy, Vol. 97, No. 6, June 1954, p. 668.

This letter is a discussion of a letter by Maurice J. Kluger shown in the March issue of The Journal of Accountancy, p. 279.

Mr. Weinwurm states in part that Mr. Kluger has made a very useful contribution to the much discussed question of how to determine period costs for the use of fixed assets in production and business operations in general by stating the problem much more clearly than is generally done, although the answer may not be the one he advocates.

11. Hope Case and Public Utility Valuation in the States, by Joseph R. Rose, University of Pennsylvania. Columbia Law Review, February 1954, pp. 189–213.

Professor Rose has made a study of state commission rate case practice since the Hope Natural Gas decision in 1944. He found that out of 43 states included in his survey, four use original cost or prudent investment as the rate base, and did so prior to 1944; nine follow fair value "according to its traditional meaning"; eight have accepted original cost as a measure of fair value; and 19 have explicitly changed from fair value to original cost or prudent investment. And so he concludes that "of all the predictions commonly made at the time of the (Hope) decision, the one anticipating the decline of reproduction cost and fair value in rate making has proved most accurate". The validity of Professor Rose's assumption is somewhat compromised by the fact that his survey does not apparently reflect some of the more recent highest state court decisions in utility rate cases. During the past 18 months there has been a half-dozen state court decisions requiring regulatory commissions to give explicit weight to reproduction or replacement value.

12. How to Get "Reproduction Cost Now, Less Depreciation", by Author L. Benjamin. NACA Bulletin, Sec. 1, May 1954, pp. 1164–1173.

Changing Price Levels

1. The Impact of Changing Price Levels on Rate Making, address by Arthur H. Dean, senior partner, Sullivan & Cromwell, before the Section of Public Utility Law of the American Bar Association at its annual convention in Boston, Mass., August 25, 1953. Public Utilities Fortnightly, Vol. LII, No. 12, December 3, 1953, pp. 817–836.

Does the Uniform System of Accounts, disregarding the shrinkage in dollar value, serve to hide the extent to which new capital is being used for replacement rather than expansion? What is going to happen, however, when the day of reckoning comes, when the ability of utility companies to attract new capital falls under the cloud of shaky investor confidence What will then happen to our facilities for producing electric power, our gas reserves, our telephone system? Will they continue to grow as the demand requires? What will happen to utility rates? These are serious questions discussed by this experienced regulatory specialist.

2. What Others Think: Utility Management's Role Under Inflation, by Robert P. Briggs, executive vice president of Consumers Power Company. Public Utilities Fortnightly, Vol. LII, No. 13, December 17, 1953, pp. 934–937.

The reluctance on the part of many regulatory agencies to recognize that the value of the dollar has changed for keeps is seriously jeopardizing the financial position of public utilities, is the opinion of Mr. Briggs. He told the Michigan Accounting Conference, recently held at the University of Michigan, that he believes a new plateau of price relationships has been reached as a result of some 10 years of inflation, and that the lower value of the dollar which has emerged from the period of inflation is permanent.

It is the belief of Mr. Briggs that under non-conversion of dollar practices the true cost of plant consumed in operations is not matched by the revenues collected from customers.

3. The Present Price Level Is Here to Stay, by Paul W. McCracken, professor, School of Business Administration, University of Michigan. Public Utilities Fortnightly, Vol. LIII, No. 2, January 21, 1954, pp. 81–89.

There are economic reasons why our present high price structure cannot deteriorate as it did in the early Thirties. Built-in high wages and other operating costs and governmental monetary policy can be expected to prevent any substantial price drop approaching a return to prewar levels. Hence this author's belief that distortions and problems caused by the drop in dollar value since 1940 must be resolved on that basis by utilities and their regulators.

4. The Effect of Growth on the Adequacy of Depreciation Allowances, by Felix Kaufman, instructor, and Alan Gleason, assistant professor, University of Rochester. The Accounting Review, Vol. XXVIII, No. 4, October 1953, pp. 539–544.

A recent issue of The American Economic Review contains an article challenging the widely held view that depreciation allowances necessarily fail to cover replacement costs during a period of rising prices. This view it is argued, ignores the effect of physical asset expansion. The article demonstrates by mathematical techniques that physical growth by itself would cause depreciation allowances to exceed replacement costs. It is possible, therefore, that the effect of rising prices on replacement costs may be completely off-set by the effect of growth on depreciation allowances.

It is the intention of this article to demonstrate and analyze these propositions through three arithmetic models and to develop the implications of this analysis.

5. Accounting for Changing Price Levels: Recent British Views, by David Solomons, B. Com., A.C.A. The Journal of Accountancy, Vol. 97, No. 6, June 1954, pp. 702–707.

A review of the British statements on whether historical cost should be maintained as the basis of accounting or whether it should be replaced by some form of replacement value. It has long been recognized in Great Britain, as in the United States, that accounting methods based on historical cost, which work well enough when the value of money is stable, have serious limitations when prices are moving sharply up or down.

6. Impact of Inflation on Public Utilities, a discussion by Frank L. Griffith, vice president and comptroller, The Peoples Gas Light and Coke Company; W. J. Herrman, vice president, Southern California Gas Company; and Robert E. Ginna, executive vice president, Rochester Gas & Electric Corporation; statement by Frank L. Griffith. Public Utilities Fortnightly, Vol. 54, No. 3, August 5, 1954, pp. 119–136.

What should responsible utility executives do about the impact of inflation on the earnings of their companies? Should they seek a positive correctice measure, even though it means drastic changes in prevailing regulatory practice? Or should they go along with the trend in view of the practical difficulties and possible boomerangs which might be incurred in trying to alter the ground rules? Or is it possible to do anything about it, even assuming that inflation is here to stay and that existing utility investors, at least, will suffer through deterioration in the integrity of their investment.

All three viewpoints, in a general way, were most thoughtfully and forcefully presented in views and arguments of the three executives.

7. Techniques for Obtaining Depreciated Replacement Costs, by C. F. Boake, consulting engineer. Public Utilities Fortnightly, Vol. 54, No. 3, August 5, 1954, pp. 137–145.

Replacement costs of property and their depreciated values have become increasingly important to utilities in "fair value" states; to all utilities because of the higher price levels.

This article on the need for obtaining depreciation replacement costs tells us about the practical ways of demonstrating the expeditious methods for obtaining depreciated replacement costs of utility property accounts. This is a very useful article covering one of the most important matters involving regulatory bodies and utility officers, and other utility rate case parties. At the present time there is an extensive discussion of the determination of reproduction cost in those jurisdictions where it is a required element of proof for a rate base.

8. Depreciation Policy Under Changing Price Levels, by Edgar A. Edwards. Accounting Review, April 1954, pp. 267–280.

Fair Value

1. Capital Cost and Fair Return—Part 1, Capital Cost Concept and Rate Regulation, by J. Rhoads Foster, managing partner, Foster Associates. Public Utilities Fortnightly, Vol. LIII, No. 5, March 4, 1954, pp. 267–282.

This is an introductory article to a series of three discussions of the controversial cost-of-capital concept in determining the fair rate of return in fixing utility rates. This installment shows how cost has different meanings for different purposes—accounting, engineering, financing, etc. The entire discussion is then related to fundamental purpose of public utility rate regulation.

2. Capital Cost and Fair Return—Part 2, The Meaning of Competitive Cost and Competitive Return, by J. Rhoads Foster, managing partner, Foster Associates. Public Utilities Fortnightly, Vol. LIII, No. 6, March 18, 1954, pp. 340–356.

In the first article in this series the various meanings of cost of capital were noted. Standards of rate regulation, including the "capital attraction standard", which have been asserted as guides in the past, were critically surveyed and the basic purpose of regulation as an alternate to free competition was reviewed. In this installment the author develops the meaning of competitive costs and competitive return under varying circumstances.

3. Capital Cost and Fair Return—Part 3, The Past versus Future Prospects in Testing Reasonable Allowances, by J. Rhoads Foster, managing partner, Foster Associates. Public Utilities Fortnightly, Vol. LIII, No. 7, April 1, 1954, pp. 421–433.

The rather extended analysis and review of the guiding principles (Part 1 and Part 2) provide the basis for identifying the capital cost concept which has validity for the purpose of utility rate regulation in the present circumstance. The term "competitive cost of capital" was used to describe this kind of capital cost. In this installment the author suggests some more specific definitions of capital cost and stresses the importance of considering future prospects as well as past test periods.

4. Determination and Recording of Property Exhaustion Costs, by Frank L. Griffith, vice president and comptroller, The Peoples Gas Light and Coke Company. Public Utilities Fortnightly, Vol. LIII, No. 6, March 18, 1954, pp. 333–339.

Stating the cost of plant investment which has been exhausted in terms of the current dollar values has become one of the challenges of present-day public utility regulation, in the light of continued post-war inflation. For the purpose of this statement here are taken as postulates the fact of decline in the purchasing power of the monetary unit in recent years, a matter having common acceptance, and the fact that reductions in the purchasing power of the monetary unit in which recordings of property cost have been made in the property accounts from year to year affect the interpretation, determination, and recording of the costs of consuming or exhausting the service capacity of all of the property of the business making the record.

5. The Need for Recognizing Fair Value, by Paul Grady, partner, Price Waterhouse & Co. Public Utilities Fortnightly, Vol. LIII, No. 6, March 18, 1954, pp. 357–365.

There are a number of arguments in favor of a return to a fair value basis for rate making, but this author takes the position that the main reason is the unfairness and inadequacy of original cost under economic conditions now prevailing and likely to prevail for the indefinite future of managed currency.

6. Fair Reward and Just Compensation, Common Carrier Service: Standards Under the Interstate Commerce Act. Book by Clyde B. Aitchison.

This study was undertaken at the instance and request of the National Traffic Committee, composed of representatives of the common carriers by motor vehicle throughout the United States. While the committee suggested the general scope, and generously facilitated the progress and completion of the study, it left the development and treatment of the theme wholly to Mr. Aitchison.

7. The Masks of a Public Utility Commissioner, by The Honorable Leon Schwartz, chairman, Pennsylvania Public Utility Commissioner. Address before the fifty-ninth annual meeting of the Pennsylvania Bar Association. Public Utilities Fortnightly, Vol. 54, No. 4, August 19, 1954, pp. 177–182.

A public utility commissioner must fulfill a number of roles. The typical regulatory statute requires him to do so. He must protect the utility consumer from exploitation in the form of excessive rates; on the other hand, he must also protect the consumer from the consequences of such low rates as to injure the utilities' ability to render efficient service and to expand plant to take care of future needs.

Regulations

1. Seventy-five Years of Public Utility Regulation in a Competitive Society, by Ralph M. Besse, executive vice president, The Cleveland Electric Illuminating Company. Address delivered before the Utility Law Section of the American Bar Association at Boston, Mass., September 24, 1953. Public Utilities Fortnightly, Vol. LII, No. 8, October 8, 1953, pp. 554–568.

Seventy-five years ago the modern era of public utility regulation was ushered in by the famous Munn v. Illinois decision of the U. S. Supreme Court. After a brief review of the political and economic history leading up to it, Mr. Besse examines what has happened since that decision.

2. Development of the Regulation of Transportation During the Past Seventy-five Years, by John B. Prizer, general counsel, The Pennsylvania Railroad Company. Address delivered before the Utility Law Section of the American Bar Association at Boston, Mass., September 24, 1953. Public Utilities Fortnightly, Vol. LII, No. 9, October 22, 1953, pp. 605–628.

Mr. Prizer states in part: "Few areas of governmental regulation of business affect more vitally the general welfare of the United States than does the regulation of transportation. The vast network of railroads, highways, rivers and canals which cover the face of the country, the airways above it, and the pipelines beneath it—this network is in a real sense the arterial and venous structure upon which trade and commerce depend. Because the various agencies of transportation serve the needs of commerce, industry, agriculture and defense, the manner in which they are regulated, as well as operated, affects not only the whole economy of the nation, but the daily life of all individuals who are a part of or who are benefited by the process of production and distribution of goods and services."

Mr. Prizer continues to discuss in a very able manner how the various steps of regulation operated and their effect on the transportation problem.

Efficiency of Operation

1. New Horizons for Railroad Engineering. Modern Railroads, Vol. 9, No. 1, January 1954, pp. 127–131.

New machines and their mode of application are bringing about a revolution in maintaining and improving the railroad fixed plant.

While all of these improvements made in addition to normal maintenance expenditures are being carried out, a real revolution is taking place in the materials and techniques of railroad track and roadway. It is a revolution that has very great potential for the future of the industry.

2. New Maintenance of Way Policies Bring Results on The New York Central. Railway Age, Vol. 136, No. 21, May 24, 1954, pp. 31–34 and 39.

Extensive revisions in organization and practices emphasizes programming, mechanization, and cycle method of conducting maintenance work.

Briefly, these objectives are to bring property-maintenance activities under a system of scientific control to the end that available funds will be expended for programmed work rather than being frittered away to a considerable extent in making repairs to weak spots. The new policies have succeeded admirably in saving time and money.

3. Greater Maintenance-of-Way Efficiency—How It Has Been Accomplished, by S. R. Hursh, chief engineer, The Pennsylvania Railroad. Railway Track and Structures, Vol. 50, No. 2, February 1954, pp. 45–47.

Advent of the five-day week and other developments have forced maintenance-of-way departments to devise and put into effect many measures for increasing the productivity of their forces. In this article, which is based on an address presented before a recent meeting of the New England Railroad Club, Mr. Hursh tells of the progress made and how it was achieved.

4. Planning and Control Through Budgeting, by Frank L. Esposito. NACA Bulletin. Sec. 1, March 1954, pp. 829–841.

Miscellaneous

1. Why Keep So Many Records? by Arthur Barcan, vice president, and R. A. Schiff, executive director, National Records Management Council. Railway Age, Vol. 136, No. 21, May 24, 1954, pp. 29–30.

The article states in part: "About 50 percent of all filed papers can be destroyed—half of the rest can be moved from offices to readily available but less costly space. Most companies in the United States are wasting 65 cents out of every dollar spent for record keeping. The cost for filing equipment alone is well over $140 million. With the volume of paperwork still rising, the files in all the cabinets are now enough to fill about 34,700 40-ft box cars."

Studies have proven that valuable space may be reclaimed by condensing existing records and eliminating excessive duplication.

2. Joint Equipment Committee (Report on) Cost of Railroad Equipment and Machinery, July 1, 1954. Association of American Railroads, Finance, Accounting, Taxation and Valuation Department, Transportation Building, Washington 6, D. C.

Brings up to date (through 1953) the report on historical costs of locomotives, freight cars and passenger cars, and average relationship costs on various types of equipment and machinery.

3. Railroad Construction Indices, 1914–1953. Compiled by the Engineering Section of the Bureau of Accounts, Cost Finding and Valuation of the Interstate Commerce Commission, Washington, D. C., August 1, 1954.

These indices summarize and record the result of studies made by the engineering section of the Bureau of Accounts, Cost Finding and Valuation over a period of years. They have not been examined or passed on by the Interstate Commerce Commission.

Court Decisions

1. New Mexico State Corporation Commission v. Mountain States Telephone & Telegraph Company. No. 5680–NM–270 P2D 685, May 8, 1954; rehearing denied June 7, 1954.

Petition by commission for court enforcement of order directing telephone company to withdraw filed rate increase; petition granted. Public Utilities Fortnightly, Vol. 54, No. 4, August 19, 1954, pp. 33–35.

The New Mexico Supreme Court holds that it has jurisdiction to determine the reasonableness of an order directing the withdrawal of a proposed telephone rate increase where the company has refused to comply with that order.

The basing of valuation for rate-making purposes during an inflationary period primarily upon reproduction cost, new figures and an estimated period in the future, as distinguished from the latest available actual figures, was considered unsound by the New Mexico Supreme Court.

2. Georgia Public Service Commission Re Atlanta Transit System, Inc. File No. 19568, Docket No. 648 U, May 12, 1954.

Application by transit company for authority to issue securities and evidences of debt; approved. Public Utilities Fortnightly, Vol. 54, No. 4, August 19, 1954, pp. 59–64.

The Georgia Commission, in authorizing a transit company to issue securities and evidences of debt, required that dividends be limited to actual earnings after provision for depreciation on a cost basis and for tax liabilities.

Report on Assignment 3

Office and Drafting Practices

W. M. Ludolph (chairman, subcommittee), B. Elkind, D. E. Field, W. A. Krauska, A. H. Meyers, L. A. Pelton, A. T. Powell, H. B. Sampson, R. L. Samuell, J. H. Schoonover, H. A. Shinkle, J. R. Traylor, W. C. Wieters.

This is a progress report, submitted as information.

Your committee has, from time to time, reported on new materials, methods and processes to aid or improve office and drafting practices.

Since its last report, only one material—an improved tracing cloth—has come to its attention.

It is claimed that the transparency of this tracing cloth is 25 percent greater than the regular tracing cloth. Also, it is said to be waterproof and flexible, as well as having better erasing qualities.

Mr. Ludolph of this committee is serving as the Association of American Railroad's representative on American Standards Association Committee Y–14, in connection with the preparation of the American Drafting Standards Manual and is collaborating with other Divisions and Sections of the AAR in this connection.

During the current year the following sections of the proposed American Drafting Standards Manual were approved by the AAR representative for ASA Committee Y–14 for submission to members of the ASA for final approval and publication.

Section 6—Screw Threads, dated June, 1954.
Section 7—Gears, Splines and Servations, dated May, 1954.
Section 11—Plastics, dated June, 1954.

W. A. Krauska and W. M. Ludolph, together with two representatives—F. Youngwerth and E. B. Platt—of the Signal Section of the AAR, are serving as a Task Group of American Standards Association Committee Y32, which has been assigned to revise American Standard Z32.2.5, "Graphical Symbols for Railroad Use".

The work of this Task Group has been completed and the revised draft of the Standard submitted to ASA Committee Y–32.

Report on Assignment 4

Use of Statistics in Railway Engineering

W. M. Hager (chairman, subcommittee), H. T. Bradley, V. R. Copp, S. Danby, V. H. Doyle, B. Elkind, M. Friedman, C. C. Haire, L. W. Howard, C Jacoby, B. H. Moore, J. K. Morrissey, C. F. Olson, W. C. Pauli, M. G. Pettis, A. T. Powell, H. L. Restall, E. J. Rockefeller, H. B. Sampson, J. E. Scharper, R. W. Scott, H. C. Wertenberger, J. L. Willcox.

(b) Standard Costs Developed by Statistical Methods

This is a progress report, presented as information.

Development of Time Study Data for Application to Track Maintenance Work

Since your committee first reported on this subject in 1952, which report appeared in the Proceedings, Vol. 53, 1952, beginning on page 494, its interest has been directed toward the development of a simplified method of recording time study information of individual work operations. The need for development of a new method became apparent because the methods first employed required too long a time to obtain sufficient data and was costly, not only from the angle of time consumption, but the high money costs as well.

Methods of Obtaining Data

Data obtained from the daily report of a section foreman or supervisor which shows the number of men worked, the number of work units completed, and the total time worked provide good cost information, but is not informative to the extent needed to determine which of any single work operation may be causing the entire work organization to produce less than the optimum rate. Such reports do not furnish information to determine whether or not individual units within the work organization are properly organized, but they are useful to determine and compare individual machine use and productivity with other similar machines.

A daily report which lists individual work operations, the number of men working on each operation, and the hours worked on each operation, has been used. It also is made by the foreman and will indicate delays to the individual operations if properly kept. This type of report was found to be unsuccessful because the section foreman, in many cases, did not have the time to collect the data in the field, and delayed making it until the day's work was done, trusting to memory. This daily report did not supply data in sufficient volume, because one day's report produced only one sampling, it was costly to administer, and the results showed great variations, probably due to inaccurate reporting.

It became apparent, therefore, that it was necessary to develop a simplified, more accurate method of measuring the optimum productive rates of machines and individual work operations. After a trial of various methods it was found that the productive results of each separate work operation could be determined most easily by relating them to a basic production unit, such as the standard 39-ft rail length. A form was designed to record the time of start of the machine or individual work unit over a rail length and time of start over each subsequent rail length. A stop watch is used to record the times posted, and delays occurring to the work are noted so they can be eliminated. The form was designed to record approximately 50 rail length units, and when the desired number

FORM FOR RECORDING TIME STUDY DATA

Division North Location Mile X 68 Track N.B.M. Supervisor Doe

Wt. of Rail Installed 132 Relieved 112 Work Operation Spike Puller SP 4

Weather Clear 90° Date June 2, 1953 Recorded By R. Roe

Rail Lengths	Time Start on Rail Lengths	Time Spent on Rail Lengths	Men on Operation	2 Machines Worked Remarks Work 1 rail and skip a rail
0	0		3	
1	2:43			
2	5:23			
3	7:41			
4	10:51			Engine stalled - 40"
5	13:21			
6	16:26			Engine stalled - 38"
7	18:59			
8	21:06			
9	23:06			
10	24:56			
11	27:11			
12	29:26			
13	31:29			
14	33:39			
15	36:06			Water boy - 20"
16	38:49			Engine stalled - 30"
17	40:39			
18	42:44			
19	44:34			
20	48:37			Gasoline - 85"
21	51:27			
22	53:02			
23	55:27			Engine stalled - 21"
24	57:07			
25	58:49			
26	61:04			
27	62:39			
28	64:23			
29	68:56			Waiting on lead machine 2'30"
30	70:36			
31	72:26			
32	74:14			
33	75:56			
34	77:36			
35	79:17			
36	81:02			
37	82:42			
38	84:37			Wait on Lead Machine 13"
39	86:19			Wait on Lead Machine 7"
40	89:06			Wait on Lead Machine 1'-04"
41	90:34			
42	92:12			
43	93:52			
44	95:27			
45				
46				

95:27 - Delay = 95:27 - 7:48 = 87:39 ÷ 44 = 2 minutes /rail length

PRODUCTIVE RATE 30:0 rails/hour

of calculations was obtained the total time worked, less delays, divided by the total number of rail lengths worked, produced an average rate of production for the machine or work unit. A speed up of data collection is possible through the use of this method. For example, in studying the use of a tamping machine one can obtain a quantity of data in 1 day which formerly might have taken 50 daily reports. In cases where a machine moves rapidly through a rail length unit, it is sometimes possible to produce a sufficient quantity of data in 30 min to 1 hr.

Use of the Data

When the machine productive rate is established, other operations supporting the tamping machine are also time studied individually, and their productive rates and manpower requirement determined. The information can then be put together in numerous combinations for determination of various, or the best, gang organizations.

The same time study method has been used in the study and development of rail laying organizations, and it has been found that one man can ordinarily collect the needed data on the individual operations in two days. Once a rate of production is established for each machine operation and hand operation in the gang, the individual units are grouped in a gang organization to produce the result desired—a gang organized so that all units will pull as closely as possible equal weight toward the desired result.

The ultimate organization of a rail laying gang is dependent either on (1) the number and type of machines available for use, and (2) the amount of labor available for use. The individual operations, both machine and hand, are tabulated and can be fitted together in various manners to produce different gang organizations. If neither of the factors stated above are controlling in the determination of the final gang organization, a gang can be organized for production of a maximum number of rails to be installed per hour, or a gang can be developed to produce the highest productive rate of rails laid per hour at minimum cost per rail.

After development of an organization based on individual unit studies, it is usually necessary to re-study the individual operations to determine productive rate changes which may have occurred because of the removal of delays caused by maldistribution of workmen, machines, etc., which were incapable of detection in the initial study.

Individual machines which perform skip-rail operations, such as spike pullers and spike drivers, develop different rates of production depending on the number of machines in use, which determines the number of rails skipped over during work. This is due to the additional unproductive walking time from the end point of the rail completed to the start of the next rail length to be worked. Therefore, in the determination of the productive rates of machines used in skip-rail operations it is usually necessary to develop the productive rate for one, two, three, or any number of machines the carrier may use.

(c) Budgetary Procedures

This is a progress report, submitted as information.

The study of this subject has been continued. A great deal of information has been collected, sorted and studied. The initial draft of a report on budgetary procedures, which will embrace the better practices and methods in use, is being prepared for the first critical review and study by the full committee.

The final report on this assignment should be ready for submission to the Association at the 1956 annual meeting.

Report on Assignment 5

Construction Reports and Property Records

W. S. Gates, Jr. (chairman, subcommittee), R. B. Aldridge, F. B. Baldwin, V. R. Copp, V. H. Doyle, B. Elkind, B. Firestone, M. Friedman, W. A. Krauska, C. E. Lex, Jr., M. F. Mannion, C. B. Martin, O. M. Miles, F. H. Neely, J. H. O'Brien, L. A. Pelton, D. E. Pergrin, W. F. Sanders, R. W. Scott, H. A. Shinkle, J. N. Smeaton, J. B. Styles, J. L. Willcox, L. Wolf.

Possible Use of Tabulating Machines in Engineering Department Procedures

This is a progress report, submitted as information.

The committee is continuing the study it has been making on the preparation of the annual valuation return to the Interstate Commerce Commission through the use of tabulating machine punched cards.

No particular difficulties are reported in the system being experimented with on the Big 4 Division of the New York Central. This year they plan to develop a set of time or man-hour reports so that labor savings, if any, may be shown.

The committee will make a study of tabulating machine methods of producing equipment property records and, if possible, will develop a recommended procedure for such work. We have started to gather the basic data for this study.

Report on Assignment 6

Valuation and Depreciation

(a) Current Developments in Connection with Regulatory Bodies and Courts

H. T. Bradley (chairman, subcommittee), R. B. Aldridge, S. H. Barnhart, M. A. Bryant, P. D. Coons, Spencer Danby, V. H. Doyle, W. S. Gates, Jr., M. M. Gerber, W. A. Godfrey, L. W. Howard, C. Jacoby, E. M. Killough, C. B. Martin, J. B. Mitchell, B. H. Moore, C. F. Olson, W. C. Pauli, H. L. Restall, J. H. Roach, E. J. Rockefeller, W. F. Sanders, J. B. Styles.

This is a progress report, presented as information

Regulatory Bodies

On December 11, 1953, the Interstate Commerce Commission issued a press release announcing the consolidation of the Bureau of Valuation with its Bureau of Accounts and Cost Finding, effective January 1, 1954. This merger was in line with the reorganization plans of the Interstate Commerce Commission. Hereafter, the name of the Bureau will be Bureau of Accounts, Cost Finding and Valuation. Thus, after 40 years as a self-contained bureau of the Commission, the Bureau of Valuation becomes a part of another bureau of the Commission.

The Interstate Commerce Commission's allocation of its appropriation for the valuation activities of the Bureau of Accounts, Cost Finding and Valuation for the year beginning July 1, 1954, contains approximately $470,838, of which $100,000, was available for pipeline work. This was a slight increase over the previous year. However, as the roster of the Commission's employees was frozen as of May 1, this will not permit the expansion of its forces. The backlog of valuation work mentioned in the 65th, 66th and

67th annual reports of the Commission will remain and it will be difficult to carry out properly the Bureau's valuation program as contemplated under the Valuation Act.

During the year the valuation forces of the Bureau were engaged principally in railroad and pipeline work, preparing many tentative and final valuations on an annual basis for all pipeline companies subject to their jurisdiction.

During 1953, Class I carriers charged Account 459, Valuation Expenses, an amount of $763,222, contrasted with $764,539 for the year ending 1952.

As of October 1, 1954, the Class I carriers were practically on a current basis in the filing of 588 returns with the Bureau, with the following exceptions: 1 carrier not filing for the year 1949, 1 for 1950, 5 for 1951, and 22 for 1952. Of the returns due December 31, 1954, 16 carriers have filed. The Valuation Order No. 3 Section of the Bureau is now 90 percent current in its field check of these returns.* The 588 returns enable the Bureau to carry into its continuous inventories and records the changes in property and their costs subsequent to the original valuation.

The Engineering Section of the Bureau, having completed revised inventories for practically all carriers through the year 1932, is engaged in bringing its inventories forward to later dates and, as of October 1, 1954, was approximately 81 percent* current (long form method). The work of the Order No. 3 Section in bringing summaries of original cost, other than land, is 94 percent* current; the summaries of original cost of land is 39 percent* current. The Land Section has completed 74 percent* of its work of adding additions and betterments to the latest appraisals which, except in a few cases, was as of 1945 or earlier.

As we have previously reported, in measuring the progress made during the year, or even for the past five years, on the railroad valuation work, it will be noted that the Bureau is not able to maintain a status quo in its program, and it will be impossible for the Bureau to keep abreast of its valuation work load or to make up arrears unless its personnel is increased. On October 1 the valuation forces of the Bureau totaled 62 employees, of which 22 were in the Engineering Section, 26 in the order No. 3 Section (16 office and 10 field), and 14 in the Land Section (9 office and 5 field).

Elements of Value as of January 1, 1952

The Bureau of Accounts, Cost Finding and Valuation prepared its estimates for the Class I carriers covering the standard elements of value as of January 1, 1953, and released them March 1, 1954.

Filing of Returns on B.V. Form 588

On April 26, 1954, the Interstate Commerce Commission issued a notice stating that effective with the reports for the year 1953, all railroads, excepting Class I and those affiliated with the Class I railroads, would be relieved of the filing of annual reports on B.V. Form 588 until further notice. Returns on this form show the units of property added and retired, together with their costs. However, this did not relieve these carriers from keeping the underlying records from which these returns were prepared.

Report of Committee on Valuation, National Association of Railroad and Utilities Commissioners

In November 1954 the Committee on Valuation of the NARUC issued a report supplementing the one of September 1953, described by your committee in its report for 1954. The NARUC report consists of 11 pages of text, with three appendices, totaling

* Based on 8,940,000 mile-years from basic valuation dates through 1953.

18 pages. Copies may be secured from the Office of the Secretary, NARUC, 7418 Post Office Building, Washington, D. C., at 50 cents per copy.

In line with its previous policy the report states that its intent is to bring the record up to date without taking any position in controversial matters. It also reiterates its statement that the Supreme Court's decision in the Hope Gas Case, while allowing commissions great latitude in fixing rates, does not lift all constitutional restraints and has not adopted original cost as the rate base for the test of confiscation.

With respect to the rate base the report points out that 10 states are currently giving some recognition to fair value; these being Arizona, Delaware, Illinois, Indiana, Maine, Maryland, Montana, New Mexico, Ohio, and Pennsylvania.

The report reviews various methods for determining a rate base valuation. One of the objections to finding cost of reproduction new and cost of reproduction less depreciation is the time and expense involved in such procedures. An alternate plan described is the calculation of trended original cost by applying appropriate index numbers. Under this method the investment is broken down by years of placement and index numbers are used to trend original cost up to current levels. One objection to the plan is the difficulty of developing accurate index numbers.

Another method advocated is described as original cost adjusted for changes in the value of the dollar. The investment is broken down by year of placement and the segments are then expressed in terms of current dollars by an index that measures changes in the value of the dollar, such as the BLS Consumer Price Index, or the Wholesale Price Index. An objection of this method is that general price indices are not representative of changes in material and labor prices affecting plant cost.

The report also deals with the subject of depreciation and other factors which may affect the rate base. It points out that the leveling off of prices in the last 20 months or so has not materially diminished the regulatory or rate making problems brought about by the imbedded inflation.

Appendix I reviews important decisions made by regulatory bodies and courts affecting valuation for rate making purposes. Appendix II consists of quotations from testimony from expert witnesses on rate of return. Appendix III is quotations on depreciation from 1953 annual reports of non-regulated industrial companies.

The report is well written and contains much valuable information.

Cost of Driving Poles and Ties

The Internal Revenue Service recently issued a ruling (Revenue Ruling 54–356; IRB 1954–34) that the cost of driving poles in the roadbed of railways to correct the effect of water pockets and mud heaves, as well as grouting expenditures, is now deductible as an operating expense for income tax purposes. Prior to this time the Internal Revenue Service did not agree with rules of the Interstate Commerce Commission on pole driving. This ruling also provides that amounts capitalized in prior years may be amortized through deducting from income until recovered. See also *Kansas City Southern Railway Co.* v. *United States* 112F, Supp. 164 mentioned in the 1954 report of this committee.

Court Decisions

In the Akron, Canton & Youngstown Railroad case, decided June 25, 1954 (22 TC No. 85), the Tax Court of the United States held that this company was not required to reduce its basis for roadway property by a 30 percent reserve for depreciation accrued during the period when the taxpayer's predecessors were using the retirement method of accounting, and that the taxpayer is entitled to deduct depreciation on such property in such annual amounts as will permit the recovery of 100 percent of the cost over the remaining life of the property. This particular taxpayer was a newly organized corporation as of February 1, 1944, when it acquired the properties of two predecessors.

The case also involves the question of whether the basis of so-called nondepreciable property retired during the taxable years must be reduced for the purpose of computing the retirement deductions, by depreciation sustained prior to March 1, 1913. Following the Boston & Maine and other precedents, the Tax Court held that no such adjustment should be made.

Report on Assignment 6 (c)

Development of Depreciation Data

Important changes in existing tax law in regard to depreciation were made when the 83rd Congress approved Section 167. Depreciation, of the Internal Revenue Code of 1954, Public Law 591, on August 16, 1954. It offers two additional options as to method of computing depreciation accruals and rates for installations subsequent to December 31, 1953:

(a) Declining balance method (limited to twice the straight-line rate).
(b) Sum of the years-digits method.

Both of these options will "liberalize" the law in enabling higher annual accruals in the early part of the service life of depreciable property. While there is much merit in these methods, their adoption should be undertaken only after careful investigation, not only as to their effect on future installations, but also as to the resulting effect on depreciation rates for existing assets which will be placed in the category of frozen or static property.

Report on Assignment 7

Revisions and Interpretations of ICC Accounting Classifications

M. Friedman (chairman, subcommittee), S. H. Barnhart, B. Firestone, W. S. Gates, Jr., W. A. Godfrey, W. M. Hager, C. B. Martin, B. H. Moore, J. H. O'Brien, M. G. Pettis, J. H. Roach, H. B. Sampson, J. R. Traylor, J. L. Willcox.

This is a progress report, presented for information only.

Your committee has made several progress reports relative to the status of ICC Subject 439 "Units of Property and Other Related Matters". This subject was originally submitted to the Accounting Division of the Association of American Railroads by the Bureau of Accounts and Cost Finding of the ICC on July 31, 1951. It proposed certain revisions of the instructions relating to the accounting classifications and also prescribed a list of units for the depreciable road and equipment accounts, the cost of which should be written out of the investment accounts when such units are retired and replaced. The Accounting Division recognized the importance of the subject as an engineering as well as an accounting matter and appointed a working committee consisting of engineers and accountants to study the subject and recommend changes in the ICC proposals that would eliminate the objectionable features and be acceptable to the railroads. The four engineers appointed to the working committee are members of the AREA and its Committee 11.

The working committee and the subcommittee of the AAR Accounting Division held several meetings among themselves and conferences with representatives of the ICC Bureau of Accounts, Cost Finding and Valuation, at which various differences between the original ICC proposals and the railroad recommendations were discussed. The membership of Committee 11 was currently advised at all of its meetings of progress made in these conferences, and the reports of Committee 11 to this Association during the period of the negotiations also referred to the developments in the matter.

As a result of the conferences, the ICC Bureau of Accounts, Cost Finding and Valuation submitted a revised proposal dated May 20, 1954, which is considered satisfactory to the railroad representatives. Committee 11 was advised of this development, and after discussion of the revised proposal the committee adopted a resolution approving the actions of the working committee and so advised the AREA Board of Direction.

The revised proposal modifies the Uniform System of Accounts as follows:

(a) Prescribes a list of accounting units to designate those items of property in the depreciable road and equipment accounts, the cost of which shall be written out of the property accounts when the property is retired and replaced.

(b) Adds instructions for the accounting to be followed relating to "changes in line of road" and "relocations of yard tracks".

(c) Adds a "major renewal rule" applicable to roadway facilities and equipment, and instructions for the accounting relative thereto.

We are advised that the proposal, dated May 20, 1954, was circulated among the members of the AAR General Committee of the Accounting Division and that it was approved by a majority of that committee.

The ICC issued a notice to all railroad companies, dated October 12, 1954, advising that its Division 1 had approved the modifications to the accounting procedure outlined above. The changes in the accounting rules and the list of units attached to the notice are identical with those in the proposal dated May 20, 1954. The notice requires that any objections to the modifications must be filed on or before Nov. 22, 1954, and that unless otherwise decided after consideration of objections so filed, an order will be entered making the modifications effective Jan. 1, 1955.

No changes in the Uniform System of Accounts, or of its interpretations that are of interest to engineers, have been made since the last report of your committee.

Report on Assignment 8

Simplification of Records to Determine Original Costs of Tracks To Be Used in Their Retirements From the Investment Account

L. W. Howard (chairman, subcommittee), R. B. Aldridge, S. Danby, V. H. Doyle, B. Firestone, W. S. Gates, Jr., M. M. Gerber, W. A. Godfrey, C. E. Lex, Jr., C. B. Martin, J. K. Morrissey, F. H. Neely, J. H. O'Brien, C. F. Olson, W. C. Pauli, D. E. Pergrin, E. J. Rockefeller, H. B. Sampson, J. B. Styles, L. Wolf.

During the years subsequent to the federal inventory, the basic valuation records of the average carrier have grown to number many thousands. This poses a problem in determining the ledger value of tracks or parts of tracks for retirement purposes, because carriers who do not maintain or have not maintained some systematic procedure for recording property changes in tracks over the years, must depend on an index of the various Authorities for Expenditure and/or Retirement, and must then laboriously trace through all individual completion reports pertaining to any one track to determine the ledger value retirement.

The problem facing carriers today, which resulted in the instigation of this subject, is complicated by the facts that: (1) Present carrier records number into the many thousands; (2) many of the records are old and are deteriorating under constant use; (3) personnel originally engaged in the basic valuation and subsequent procedures are rapidly nearing retirement age, and the difficulty encountered in trying to replace that trained personnel forces us to seek some means of relief from the detail and drudgery of developing track retirement information.

Your committee proposes to pursue this subject along two lines: (1) Develop methods to determine average costs to be used for track retirements; (2) outline a procedure whereby a carrier, which does not now have a record for each mile of main track and individual side tracks, can most economically create such a record. It will list in detail all information from the pertinent completion reports in such a manner as to simplify the development of retirement information.

Your committee presents the foregoing as a progress report, and the subject will be continued for study.

Special Report on

Joint Projects and Joint Facilities*

By Wm. S. Gates, Jr.**

The scope encompassed by this subject is much too extensive to be fully treated in a short paper, but we shall attempt to develop some historical information concerning it and indicate a few interesting facts in the hope that we can convince the membership of the AREA that the subject is both interesting and useful. We hope to stimulate the interest of the engineering departments so they will want to do something about the issues into which this subject leads.

We have a very broad subject here, and I know full well that my chief trouble is going to be to confine it, to "house" it, as it were, and so prevent its rambling. Therefore, suppose we start with a definition. A Joint Project, as we know it in railroad circles, is any project in which two or more carriers unite their efforts in the construction of a facility for their mutual benefit. They proceed to draw up an involved contract to cover the construction of the facility and its subsequent operation. Likewise, a Joint Facility is the result of the construction of a joint project, or is a facility, either wholly or jointly owned, used by two or more carriers.

I think I am correct in saying that we find joint facilities only in the public utility organizations, the railroads, electric companies, telegraph and telephone lines, air lines, pipelines, and the like. They are caused by overlapping services, and through their use much duplication of facilities is avoided.

It is safe to assume that the first joint project or joint facility came into being rather early in the railroad picture. A review of early history shows a number of references to trains running into each other at grade crossings. As time went along these references

* Committee 11—Records and Accounts, as a part of its meeting programs from time to time, includes informal papers or talks by specially qualified members or others on subjects of special interest to the committee. This paper is a condensation of such a presentation before the meeting of the committee in New Orleans, La., on January 13 and 14, 1954.

** Assistant to Auditor—Valuation, Chicago & Illinois Midland Railway, and a member of Committee 11—Records and Accounts.

seemed to drop away, indicating that someone had done something. I do know that people do not write about joint facilities very often. The indexes that I have examined are very quiet on this particular subject. One of the very few articles found was in Vols. 34 and 35 of the AREA Proceedings, where a subcommittee of our own Committee 11 devoted a few pages to the subject. Here was displayed the methods that can be used to determine the base cost of a joint facility and suggestions as to how these costs and valuations may be currently kept up to date. The Proceedings also displayed an excellent method of identifying property through the use of tabulated sheets and drawings. Much time and effort were put into this report, which is entitled The Joint Facility Base Record, and I commend it to you.

For an adequate background for this paper, I consulted several histories of the post Civil War days, and, among other things, found a reference to a controversy in 1868 between the Horn Pond and the Arlington & Fitchburg in the use of their properties and the hours they could be used. Another interesting article was one on railroad combinations in 1883, which resulted in the opening step of a consolidation. Other articles in the same period were interesting, but one could scarcely call the slugging and the back-room tactics of those days "joint facility efforts". Those boys played the game rough and joint facilities were probably the farthest from anything they had in mind. In 1887 there was quite an ado about railroad crossings in Buffalo. In the section on 1890, I saw the title, Complicated Crossings. Now, thought I, I *really* have something. You know what?—Even in that dark age the Pennsylvania and the Baltimore & Ohio were getting us honest railroads confused. Here I found a description of leads into an industry where, in an area of 100 sq ft, some wild engineer's vision had dreamed up a track layout that included 17 railroad crossings. It was almost like backing into the St. Louis terminal.

Let us go back for a minute to the Horn Pond Railroad. This was located near Boston, so I had our Boston member look into the matter; however, neither his people nor the commissioners of corporations for the Commonwealth of Massachusetts was able to find any record of the Arlington & Fitchburg Railroad. They did find the Horn Pond. It was located in 1854, just 100 years ago. The line was just ½ mile long and ran from what is now the main line of the Boston & Maine, between Boston and Concord, down to a pond at the foot of a hill. Its purpose was to provide transportation from the pond to an ice house. As they no longer use pond ice, the line now serves a pumping station located on the shore of the pond. These things make interesting reading and it is hard to tear yourself away, but I do not feel they have much point here. We must finally come down to the present and face the fact that joint facilities are an accomplished fact. The future will probably see more of them, rather than less. It has become too expensive and impractical to maintain duplicate facilities.

A typical example of a joint facility inside a big city is noted in the historical records of the Illinois Central, on its line in Chicago known as the St. Charles Air Line. This connecting line runs west from the lake about ½ mile south of the Illinois Central depot and serves as a connection between the lines east and west of the south branch of the Chicago River.

Back in 1852, after the IC had constructed its line along the lake front, it found that it was going to be necessary to connect with the Galena & Chicago Union (now the C&NW) and the Chicago & Aurora (now the CB&Q), which had constructed lines along the west bank of the south branch of the Chicago River. They drew up a memorandum of arrangement on March 6, 1855, in which each of the lines—the IC, MC, G&CU and the C&A, held 25 percent ownership in the St. Charles Air Line property. The Illinois state legislature legalized this joint ownership 10 years later, on February 16, 1865. The line itself was constructed and placed in operation March 30, 1856, was doubled tracked in 1868, and elevated over the city streets in 1897.

By 1933, 14 other roads gained use of this Air Line for connecting service, and a fee system was set up. Profit, if any, is distributed equally among the four original owners. To show how important a joint facility can become, we find today the following use of this line:

IC—This road uses the Air Line as a main track for all its western lines' business—both freight and passenger; also for all its transfer freight business with the C&NW, CB&Q, GM&O and AT&SF, and for the delivery of perishable freight and passenger equipment to all lines in the city.

C&NW—This road uses the Air Line for all its interchange business with the IC, MC, NYC, CRI&P, and NYC&StL. It delivers perishable freight to the tenants of the C&WI via this route; also passenger equipment to and from all lines using the Central, La Salle St., and Dearborn stations.

CB&Q—This road uses the Air Line for all its interchange freight business with the IC, NYC, CRI&P and NYC&StL; also for perishable merchandise and stock to the MC.

MC—This road uses Air Line for delivery of merchandise, stock, perishable, and local switch business to the C&NW and CB&Q, and for passenger equipment to all lines in Chicago.

The Illinois Central makes its bills for construction, maintenance, and operation in accordance with the General Managers' Agreement, and adds the established 10 and 15 percents to cover supervision and handling. Ownership has remained at 25 percent each, but operation and maintenance are divided on a wheelage pro-rate.

Valuation Problems Created by Joint Facilities

As we are primarily a valuation group, I should like to spend a little time on the problems that joint facilities create in our work. By the time the federal valuation came along, the joint facility was firmly established in the railroad picture. Its most simple form was the interlocking plant where two roads cross each other. It was necessary for the valuation party to determine what this interlocking plant included, and to determine also the proper division of ownership. In many cases, what had begun as a simple 50–50 deal had developed into a real complexity. Often one road wanted something added and the other did not. They settled the question by saying, "You go ahead and build it if you want to. It won't hurt us, but you'll have to pay all the costs". It is not hard to picture the ICC field force chief being confronted with conflicting statements. He often found himself both judge and jury.

However, after the chief had made up his mind, he inventoried the physical facility and proceeded to detail it on one of the inventories, from which it finally found its way into that road's engineering report, in full detail. The secondary road's inventory and resulting engineering report just mentioned the facility with a very brief description, and recorded the total reproduction and less depreciation costs, the percentage of ownership, and each road's share of the total costs. Why was this simple method not continued in the Valuation Order 3 returns? Is our product an improvement over the simple manner that was set up in the basic inventory? If you take the sum total of all the reporting from a five-road-owned interlocking plant that was on the original engineering report, how near will it describe the actual physical facility of today, and how close will it come to representing either its reproduction or original cost?

Another very troublesome thing in valuation in connection with joint projects is the variance in the handling of the accounting, valuation, and depreciation. In developing data for this paper I had the pleasure of reviewing an 11-page memorandum written to an auditor of construction a few years ago. This paper showed great concern about these differences, the troubles they were causing at that moment, and the troubles they were going to cause in the future. The memorandum carries a comment in one paragraph, "The Bureau of Valuation modified this rule." At another point it said, "It would be desirable if an agreement could be reached whereby investment and valuation reporting were identical, thereby eliminating the need for development and handling a different set of figures for the two purposes." To that I can say a heartfelt "Amen." But, it adds, "Our depreciation base includes no donations. Therefore, in setting up a project which includes donations, we are confronted with an additional problem. Thus, we have three separate considerations, i.e., investment, valuation, and depreciation base. Each of these is different. The only way to secure absolute control over each would be to set up an additional summary to show the amounts for each purpose."

We all have the same problems, and I toss one more into the hopper just to complete the confusion. I maintain two separate depreciation books because the IRS and the ICC are at variance with each other in their handling of Account 1, Engineering, in their depreciation setup. In one case Account 1 has an identity of its own with a rate of its own, while in the other it is split among the various accounts benefited by the engineering services, and takes their depreciation rate.

Basis for Joint Facility Billing

As I said at the beginning, the difficult thing about this paper is to keep it from roaming. I see that we have gone off on a branch line. Let's get away from valuation for a while. Committee 11 is a division of the AREA, and as such we are the watchdogs of "Records and Accounts" for the benefit of the entire Association. In reviewing the addresses that were made at the 1953 annual meeting of the Accounting Section of the AAR, I found an adress by E. G. Parker, auditor of disbursements of the Nickle Plate. There is much in Mr. Parker's ideas that will help the members of the AREA. We, or rather the engineering department through its maintenance of way and construction divisions, furnish the basic working tools of the accounting department. We are the ones who supply them with figures. Mr. Parker said that the AAR Disbursement committee has on its docket the development of new methods and procedures to simplify joint facility bills and vouchers. He believes that the simplification should be originated by the accounting organization. He reaches the conclusion that the most simplified method would be a flat rate per car, per train, per ton, or some other easily measured traffic unit. But, in a period of changing costs a flat rate can be quite deadly, indeed. He brings in the engineers by saying that flat rates covering maintenance could be based on the judgment of engineers of the lines affected, and that after giving full consideration to actual expenses incurred, engineering judgment may be used to establish the rates that are deemed advisable. He then goes on to list a number of interesting details. After a couple of pages he comes up with this very interesting statement: "One of the major savings and results to be obtained through the adoption of a simplified basis for joint facility billing is the relief that will be given field forces from compiling daily, weekly, monthly or periodical reports which now form the underlying data supporting the itemized bill."

There is meat in Mr. Parker's remarks. Looking back through the AAR Accounting Division's reports and the AREA Proceedings, we find joint facilities cropping up again and again. Joint facilities, my friends, are sturdy animals and, like the cat, they seem to be equipped with many lives. You cannot kill them off nor can you shake your head at them and ignore them. Are we interested enough to look into this? Do we or do we not have a "Joint Project" with Mr. Parker's group?

I trust I have made it plain that what I am talking about is the vast detail reporting contained in the joint facility system, that has its origin way down on the section, or in the signal gang, or on some bridge and building outfit. After I looked into what the Peoria & Pekin Union was doing and what the Illinois Central was doing on a joint line which we use, and what my own road was doing with a Baltimore & Ohio, Wabash and Gulf, Mobile & Ohio operating agreement, I decided that someone was wasting an awful lot of time and effort. Time quickly builds into money in these days of high wages.

It seems that after one has maintained and operated a joint facility for a period of 10 years or more, and has rendered detailed reports concerning each bolt, nut, screw, nut lock, bus bar, relay, tie, rail, and switch lamp, he should have a considerable amount of available data. Why could not a good engineer, a good valuation man, and a good accountant sit down and produce order out of the chaos which such data holds? Could not these men tell us of the standard of maintenance, the major repairs, or the special maintenance? It would be simple to separate labor from material costs, and work equipment rentals from transportation of material; overheads would fall out and classify themselves. All of this might lead to a base figure that could be trended to bring it to a current period, which would then represent current cost of maintenance and operation according to definite standards. What does the additional detail that one piles up year after year add to the picture? If we could get an equitable representation of cost by a short method with less work we could apply whatever traffic measures are used to divide it among the users. Our savings in reporting costs, accumulating, sorting, and checking figures, and finally getting them down on paper, would be considerable. And, what the AREA is interested in, can't you hear the shout of relief when you tell your section, bridge or signal foreman that he can forget that extra report he must make on joint facilities from this point out? We should have an interest in this problem. Most of us on Committee 11 are valuation men. These things do not come under our direct assignment and in most cases we have little to do with them; but, as the AREA's "Accounts and Records" representatives, we should call the attention of our chief engineers to them.

A logical method of directing attention to the problem would be to ask a few questions, so, a set of five questions are offered for your consideration. Much interest may be developed from your road's answers to these questions; and, if your road has many joint facilities, a little time spent thinking on this problem might well prove very worthwhile.

1. Valuation Department

Would it be worthwhile to determine if a single completion report, with its resulting BV 588, prepared by the "Construction-Carrier", would not serve as the single detailed return to the commission under Valuation Order 3, and have the "Secondary-Using-Carriers" report only the account totals representing its share of the ownership in the facility?

2. Engineering Department—Maintenance Section

What, if any, reports are required of the engineering department—maintenance section on a joint facility that are not required in maintaining a wholly owned and used facility? Who makes these reports, and do they impair the effective use of his time on his primary assignment? *Are there any identifiable "out-of-pocket" expenditures incurred in the reporting of the maintenance of jointly used facilities?*

3. Legal Department

Can cauculated figures, based on a proper study, be substituted for the detailed lists of actual labor and material that are spelled out in a standard joint facility contract, and how far can one go without violating the intent of the contract to bill a prorate of actual costs plus specified overheads?

4. Engineering-Accounting-Valuation Departments Jointly

What can the engineers of the AREA contribute toward a joint study on the simplification of the record keeping for maintenance of joint facilities that might lead to the elimination of a portion of the requirements that are developed by consideration of Item 2? Are the items developed by a study of Item 2 serious enough to cause the AREA to desire their elimination?

5. Railroad as a Whole

How many people are involved in the task of reporting, accounting for, billing, and paying for jointly-used facilities? Are there any possible savings through the reduction in the required effort?

This paper has touched very briefly on joint facilities. I have only scratched the surface. This joint project discussion is for our mutual benefit, and if by it I have aroused any ideas, or motivated any progressive action, I shall consider the time well spent. I have said nothing that most of you do not already know, but perhaps I have set it forth in a different manner. We will now let it tumble and churn for a while. Who knows? Something useful might develop from it.

Report of Special Committee on Continuous Welded Rail

L. F. Racine, *Chairman,*
H. C. Archibald
S. H. Barlow
T. A. Blair
Blair Blowers
C. B. Bronson
E. J. Brown
H. B. Christianson
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L. S. Crane
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I. H. Schram
T. C. Shedd, Jr.
H. A. Siravo
R. P. Winton
Edward Wise, Jr.
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Fabrication.

   Progress in study, but no report.

2. Laying.

   Progress in study, but no report.

3. Fastenings.

   Progress in study, but no report.

4. Maintenance.

   Progress in study, but no report.

5. Economics.

   Progress in study, but no report.

Special Committee on Continuous Welded Rail,
L. F. Racine, *Chairman.*

AREA Bulletin 521, February 1955.

A

Report of Committee 1—Roadway and Ballast

B. H. CROSLAND, *Chairman,*
W. T. ADAMS
R. A. ANDERSON
E. W. BAUMAN
R. H. BEEDER
F. N. BEIGHLEY
C. R. BERGMAN
L. H. BOND
J. E. CHUBB
H. W. CLARKE
B. S. CONVERSE
M. G. COUNTER
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L. V. JOHNSON
W. T. JOHNSTON
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R. R. MANION
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F. H. MCGUIGAN
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STANTON WALKER
C. E. WEBB
A. J. WEGMANN
CHARLES WEISS
A. A. WINTER
J. C. WOODS
R. C. YOUNG
W. L. YOUNG
Committee

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

No report. (See reports on Assignments 2, 4 and 8).

2. Physical properties of earth materials:

(a) Roadbed. Load capacity. Relation to ballast. Allowable pressures.

(b) Structural foundation beds, collaborating with Committees 6 and 8. Delete from the Manual material under heading "Physical Properties of Earth Materials", pages 1–1–38 to 1–1–44, incl., and adopt for inclusion in the Manual material appearing in Vol. 55, 1954, pages 616 to 628, incl. .. page 679

3. Natural waterways: Prevention of erosion.

Progress report, presented as information .... page 679

4. Culverts:

(a) Conditions requiring head walls, wing walls, inverts and aprons, and requisite therefor.

No report.

(b) Specifications for high-pressure gas lines.

Section B. For non-flammable substances, presented as information for purpose of soliciting comments and criticisms prior to submission in 1956 for adoption and inclusion in the Manual .... page 688

(c) Methods for installing culverts inside of existing culverts.

Final report, submitted for adoption and inclusion in the Manual .... page 690

THE COMMITTEE ON ROADWAY AND BALLAST,
B. H. CROSLAND, *Chairman.*

AREA Bulletin 521, February 1955.

Report on Assignment 2

Physical Properties of Earth Materials

(a) Roadbed. Load Capacity. Relation to Ballast. Allowable Pressures.
(b) Structural Foundation Beds, Collaborating with Committees 6 and 8.

R. R. Manion (chairman, subcommittee), C. E. Dysart, J. G. Gilley, J. W. Poulter, R. J. Scott.

Your committee this year presents, under combined Assignments (a) and (b) a recommendation for the withdrawal of the present Manual material under Physical Properties of Earth Materials, pages 1–1–38 to 1–1–44, incl., and the substitution therefor as Manual material the portion of the Proceedings, Vol. 55, 1954, under the same caption, pages 616 to 628, incl. The proposed Manual material includes the present information in the Manual, with additions, plus Specifications for Test Borings. A few editorial revisions have been made in the latter.

Report on Assignment 3

Natural Waterways: Prevention of Erosion

L. H. Jentoft (chairman, subcommittee), R. A. Anderson, M. B. Davis, F. H. McGuigan, A. J. Wegmann.

Your committee submits the following report as information on that part of its assignment covering the prevention of bank erosion in natural waterways of the alluvial type by the use of steel jetties.

The problem of bank erosion in natural waterways carrying heavy loads of silt has been attacked in various ways in the past with results which have not always been satisfactory from the standpoint of economy and effectiveness. Some of the commoner types of bank protection include the driving of piles, the placement of heavy rip rap, the construction of rock-filled crib work, and the facing of embankments with concrete. These rigid types of protection have been unsuccessful in many cases where severe erosive action is involved due to undercutting, resulting in partial failure or even complete failure, and the washing away of the structure or materials involved.

As the inadequate solution is the most costly solution in the long run, the need for a better answer to the problem has resulted in the development of a flexible type of protection using so-called steel jetties. These jetties were introduced in the early 1920's, and in recent years have been used more and more widely in the midwestern and southwestern parts of the country. The users include railroads and highway departments, and more recently the Corps of Engineers, U. S. Army, and the Bureau of Reclamation. The district engineer of the Corps of Engineers at Albuquerque, N. M., issued in June 1953 a report on the use of steel jetties for bank protection on alluvial streams which contains a comprehensive discussion of the subject and which is recommended reading for those interested in this problem.

The purpose of a line of steel jetties is accomplished by lowering the velocity of the water, which results from the obstruction to flow offered by the components of the units and by the drift which is caught in the jetties. The reduced velocity lowers the carrying power of the water and causes it to drop a portion of the load of sediment which is present in the flood flow of streams with erodible beds. This deposit of sediment eventually results in the bank building up, vegetation begins to grow, and a new bank line is established at about the front of the jetties. In some cases further scour takes place and the jetties sink into the bed of the stream as a result. If this sinking proceeds far enough, another row of jetties is simply placed on top of or a little behind those which are buried.

The functioning of a steel jetty installation is shown by three photographs taken on a large stream in the Midwest. Fig. 1 shows the severe erosion of the river bank; Fig. 2 shows the jetty units in place; and Fig. 3 shows the same location after silting was well established.

The design of a steel jetty installation should be based on an adequate topographic map or aerial photograph. A preliminary alinement can thus be determined and the final location then determined on the basis of experience with the particular location and judgment as to the results which can be expected.

Two principal elements are involved which may be designated as diversion lines and back-up retard lines. Fig. 4 shows a typical installation and illustrates the relation of these elements to each other. The diversion lines are relatively long and are usually placed approximately parallel to the bank to be protected and conforming in general to the alinement of the stream. Jetties which cut across a bend or make a sharp diversion are generally to be avoided as the units are more liable to damage when the angle of attack of the current is greater than 45 deg. A single line of diversion jetties may suffice in some cases, while in other cases two or more lines may be required, depending on the severity of the scour anticipated and the angle of attack of the stream. The upstream ends of the diversion lines are usually extended towards the bank at an angle so as to form an anchor line.

The back-up retard lines are short lines of jetties which are installed at about right angles to the main jetty line and extend back to the bank where they are anchored. Their purpose is to reduce further the velocity of the current and to prevent flow from developing behind the jetties and causing them to be outflanked. The spacing of these back-up retard lines may vary from 200 ft with a slight angle of attack by the stream, to about 75 ft, or even as little as 25 ft, with a sharp angle of attack.

One type of steel jetty in use, which may be designated as Type A, consists of units which are called jacks, each of which is made up of three 4-in by 4-in by ¼-in steel angles, each 16 ft long, which are bolted together in the center and interlaced through holes in the angles with No. 6 wire. The angles are placed back to back with their longitudinal axes at right angles to each other so that three sets of intersecting planes are formed with a common joint at the center of the unit. The wires for lacing are spaced about 15 in apart. The angles are punched at the factory for connection holes and lacing holes to facilitate field erection. The assembled unit is shown in Fig. 5, and also in the photograph, Fig. 6. The units are designed to be spaced 12 ft 6 in center to center so that 8 units or jacks are required for a single line 100 ft in length. After being placed and properly alined the units are interconnected by 2 lines of ¾-in cable, the cables being clamped together on each side of the mid-point of each unit. These cables extend continuously through the units and are fastened at each end to deadmen consisting of railroad ties, pile butts or the like.

A second type of steel jetty may be called Type B, and is made up of units which use 6 instead of 3 steel angles, each 16 ft long. The angles used are somewhat smaller, being usually 3 in by 3 in by ¼ in. These units may be set on either three or four points as may be desired, and the remaining angles used as horizontal ties near the bottoms of the units. The angles are laced with ¼-in rods and the units are tied together with ¾-in cables or rods about as described for the preceding type. Photograph designated Fig. 7 shows Type B units. Because of the use of more angles and of rods instead of wire for lacing, this type offers somewhat more obstruction to the flow of water, and also affords stiffer resistance to bending from the impact of heavy drift, than the kind first described. About six units of this type are required to cover 100 ft of bank.

Another type of jetty is built with steel fascine boxes having a square cross section, about 4 ft by 4 ft, with the longitudinal corner members of 1½-in by 1½-in angles, and with girts and bracing spaced at about 4-ft centers and made from ¼-in by 1½-in bars. The construction of this type is shown by Figs. 8 and 9. Woven wire fencing is placed around the outside of the box and fastened with soft iron wire. These boxes may be made up in 20-ft lengths and extended as far as required by splicing the longitudinal rails or angles. Cables may be used for anchoring in a manner similar to that for the other types. Fascine boxes, assembled and ready for installation, are shown in Fig. 10, and Fig. 11 shows a typical installation.

Some types of steel jetties are covered by patent rights and the materials required for a complete installation can be purchased from the manufacturers already punched and equipped with all required fastenings for quick erection in the field. In many cases the manufacturer will furnish a construction supervisor, and the actual work of erection can be performed by common labor with the use of hand tools. A crew of 12 men has been found to be an efficient organization.

The materials are hauled to the site in a knocked-down condition and the units are then completely assembled at a place convenient to their final location. After assembly the units are carried to and placed in final position. If the work is being done in the water the final movement may involve the use of rafts. About 16 units can usually be assembled and positioned at one time, after which the ¾-in cables are threaded through the units and clamped in position. The natural growth of vegetation should be disturbed as little as possible. Excavation is required only where the jetty line crosses a steep bank.

The actual work of assembling and installing the jetties may be accomplished by contract or by company forces as may be found most desirable, but the materials should probably be purchased. In any event, adequate specifications should be followed, although these need not be elaborate. Specifications should cover the number and size of the angles to be used in the jacks, details for fastening the angles together, and information regarding the lacing, whether wire or rods, and the sizes and locations for these members. To secure maximum life a corrosion-resistant metal, such as wrought iron or copper-bearing steel, should be specified for the angles and rods. Spacing of the units in final location should also be covered, as well as details of the manner in which the units are to be tied together and the methods for splicing and anchoring the longitudinal tie lines. A location plan should be available to guide field installation and should be made a part of the contract if the field work is done by contract.

Failures in steel jetty installations have been few and for the most part only partial. Occasionally, heavy drift will strike some of the angles and bend them. The weakest feature in the construction is the lacing as the wires may rust and break after a few years, especially if corrosive elements are present in the water. The use of rods of corrosion-resistant metal for lacing has an advantage in this respect. Steel jetty installations are in existence with service records of 30 years and a life expectation of 50 years or better.

Costs of steel jetty installations are reported during the past two years as ranging from about $50 to $70 per unit installed. The cost for any particular location will

(Text continued on page 687

Fig. 1—Severely eroded river bank.

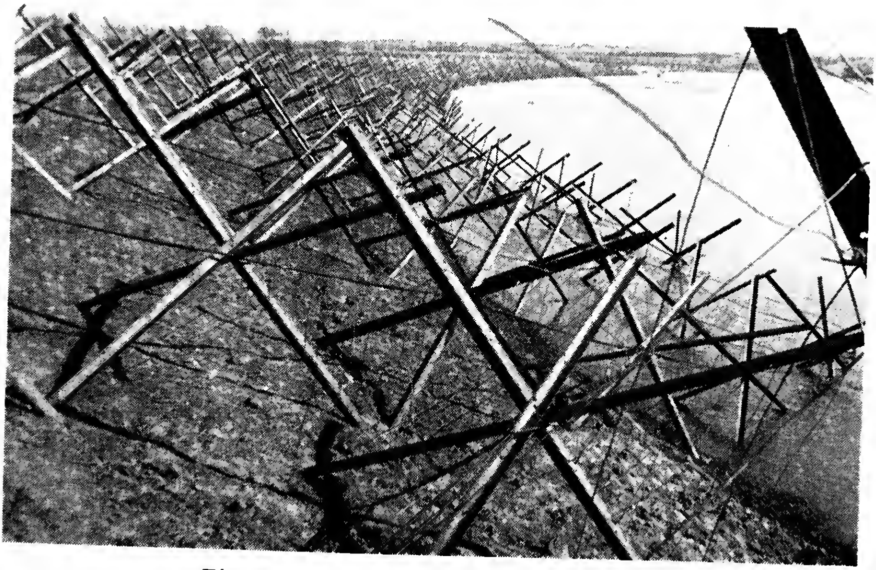


Fig. 2—Steel jetty installation in place.

Fig. 3—After silting has become established.

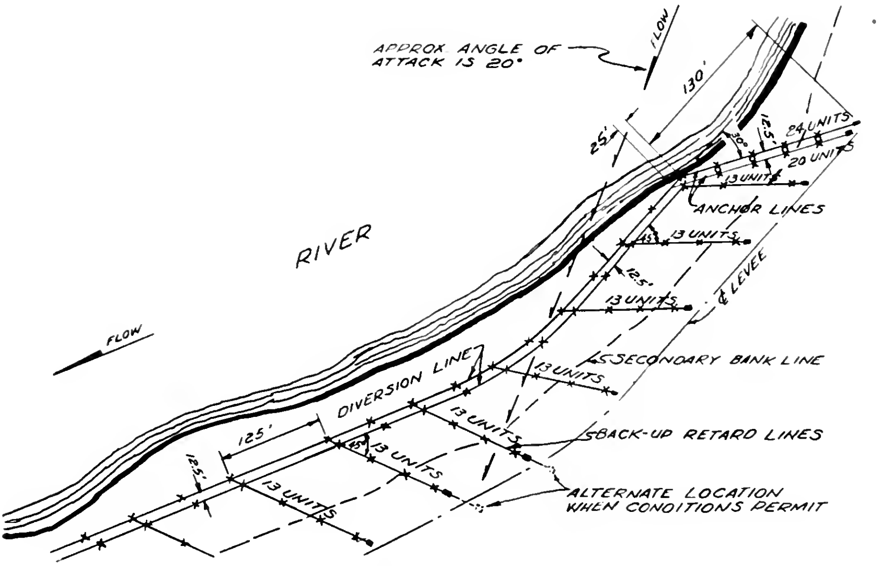


Fig. 4—Typical layout of steel jetty installation.

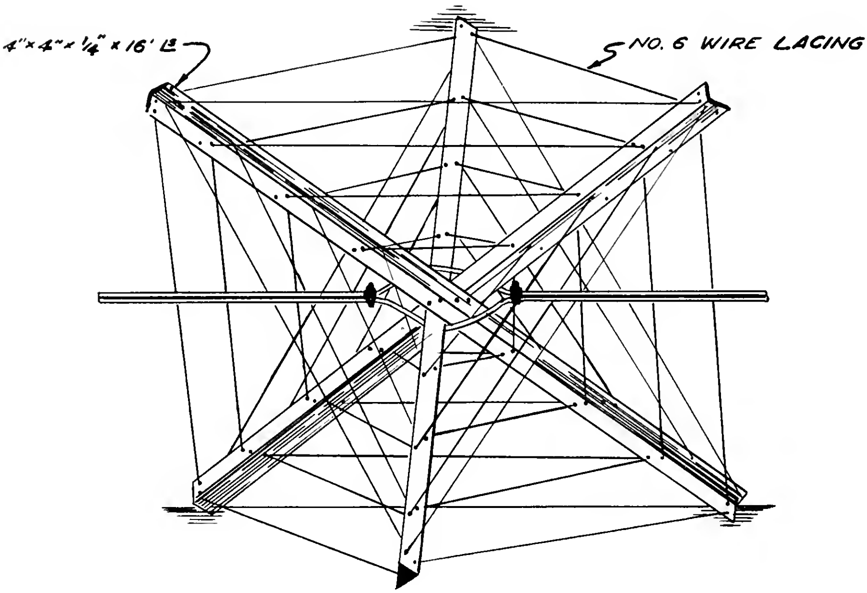


Fig. 5—Type A steel jetty unit.

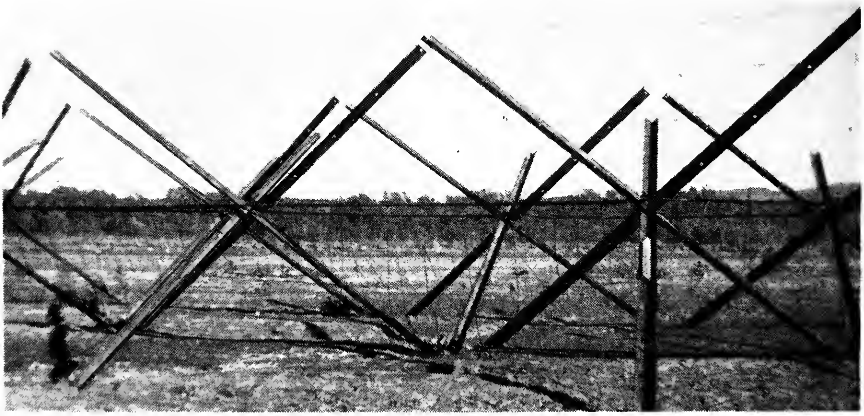


Fig. 6—Type A steel jetty units.

Fig. 7—Type B steel jetty units.

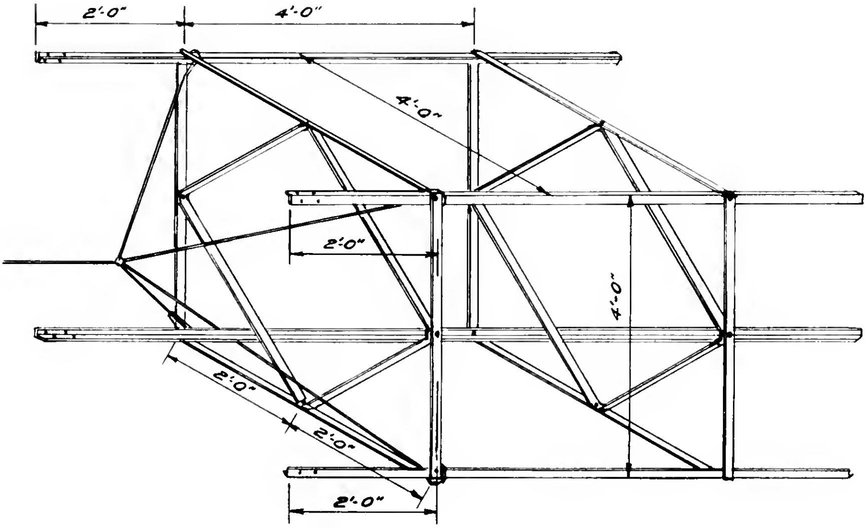


Fig. 8—Steel fascine box.

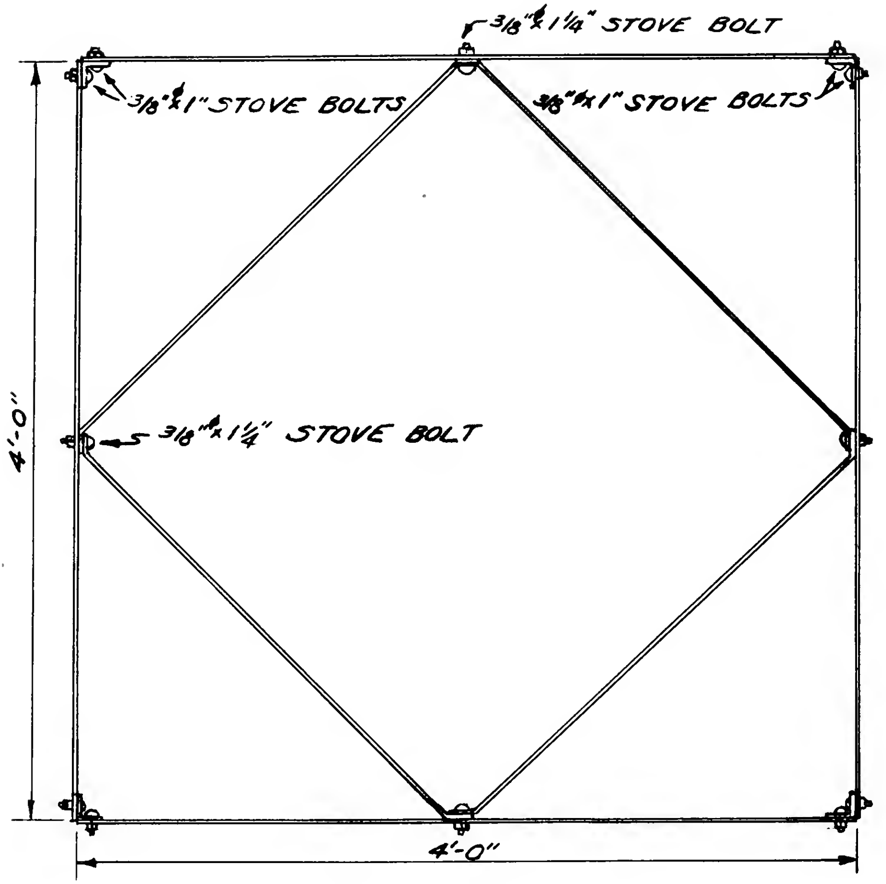


Fig. 9—Cross section of fascine box.

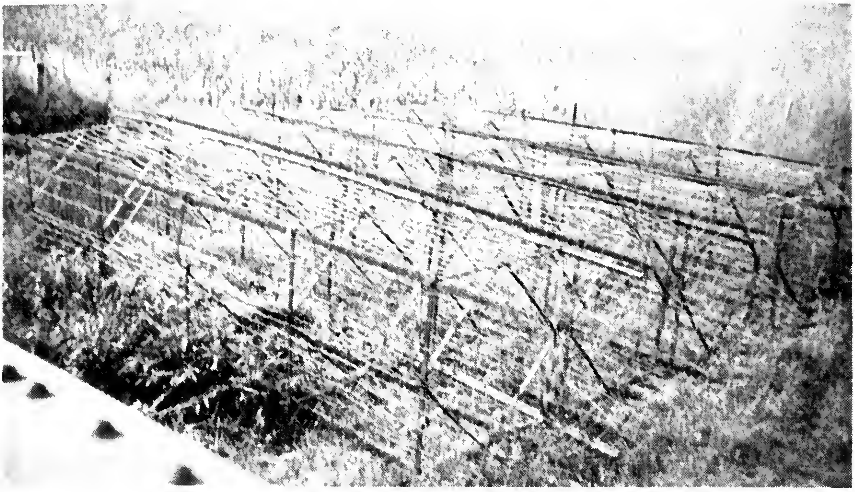


Fig. 10—Fascine boxes assembled.

Fig. 11—Typical installation of fascine boxes.

of course, depend on the current costs for materials, the current applicable wage rates, and the location and other factors having a bearing on the difficulty of construction.

In conclusion, it can be said that steel jetties, properly installed, can be made to furnish a flexible type of bank protection which is highly effective as a means of stabilizing erodible banks of alluvial streams. While special conditions may indicate different construction in some cases, the permanent results obtained, together with simplicity of construction and relatively low cost, certainly recommend consideration of the use of steel jetties in attacking the problem of bank erosion in natural waterways.

Report on Assignment 4

Culverts

(a) Conditions requiring head walls, wing walls, inverts and aprons and requisites therefor.

(b) Specifications for high-pressure gas lines.

(c) Methods for installing culverts inside of existing culverts.

G. B. Harris (chairman, subcommittee), W. T. Adams, H. W. Clarke, B. S. Converse, T. F. DeCapiteau, J. W. Purdy.

Your committee reports this year on Assignments (b) and (c) only.

Report on Assignment 4 (b)

Specifications for High-Pressure Gas Lines

Last year the Association approved, for publication in the Manual, Specifications for Pipe Line Crossings Under Railway Tracks, Sec. A. For Flammable Substances. Sec. B. For Non-Flammable Substances, of the same specifications, is now presented as information for the purpose of soliciting comments and criticism prior to submission in 1956 for adoption and inclusion in the Manual in place of the current Sec. B. For Non-Flammable Substances.

SPECIFICATIONS FOR PIPE LINE CROSSINGS UNDER RAILWAY TRACKS

B. FOR NON-FLAMMABLE SUBSTANCES

1. Scope

Pipe lines included under these specifications are those installed to carry steam, water or any non-flammable substance which, from its nature or pressure, might cause damage if escaping on or in the vicinity of railway property.

2. Installation

Pipe lines under railway tracks and across railway right-of-way shall be encased in a larger pipe or conduit called the casing pipe, in accordance with these specifications and as indicated in Fig. 4.

Pipe lines shall be installed under tracks by boring or jacking, if practicable.

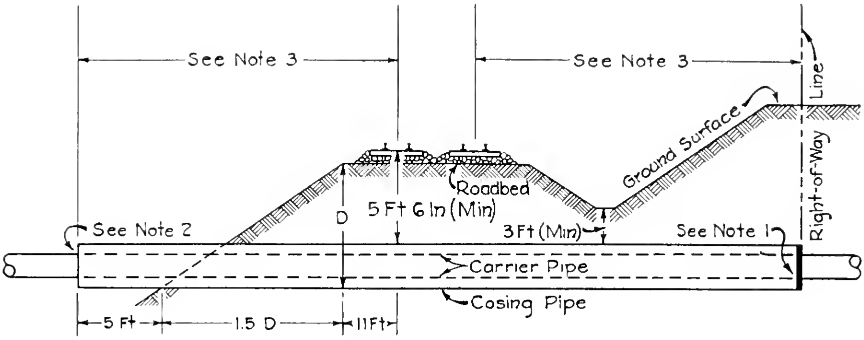
Any replacement of a carrier pipe or casing pipe shall be considered a new installation, subject to the requirements of these specifications.

3. Carrier Pipe

Carrier line pipe and joints inside of casing under railway tracks and right-of-way shall be of approved construction satisfactory to the railway company.

Joints for carrier line pipe operating under pressure shall be of mechanical or welded type.

Pipe shall be laid with slack (no tension) in the line, or with expansion joint near the point of railway crossing.



NOTES: 1. Ends of casing, when below ground, shall be suitably protected against entrance of foreign material.
2. Ends of casing, when above ground surface and above high water level, may be left open where drainage is available.
3. Casing pipe shall extend a minimum distance of 11 ft plus 5 ft plus 1.5 D measured at right angles from center line of outside track (Where D equals the depth of bottom of casing below subgrade), or to railway right-of-way, whichever is greater.

Fig. 4.

4. Casing Pipe

Casing pipe and joints shall be of a rigid, leakproof construction, capable of withstanding railway loading, and shall conform to the requirements shown under Art. 4, Sec. A. For Flammable Substances, except that seals and vents are not required.

For pressures under 100 psi in the carrier pipe, reinforced concrete pipe may be used.

Reinforced concrete pipe shall have watertight joints and conform to the current ASTM Specifications, designation C 76—Table I for diameters under 24 in—Table II for 24 in diameter and over.

5. Protection Against Corrosion

Both casing pipe and carrier pipe, of steel material, shall receive externally the same protective coating as specified in Art. 5, Sec. A. For Flammable Substances.

6. Protection at Ends of Casing

Where the ends of the casing are below ground they shall be suitably protected against the entrance of foreign material, but shall not be tightly sealed.

Where the ends of the casing are at or above ground surface and above high water level they may be left open, provided drainage is afforded in such manner that leakage will be conducted away from railway tracks or structures.

7. Depth of Casing

Depth of casing shall be the same as specified under Art. 9, Sec. A. For Flammable Substances.

8. Length of Casing

Casing shall extend each side from the center line of the outside track, measured at right angles, a minimum distance of 11 ft + 5 ft + 1.5 D (where D equals the depth of the bottom of the casing below subgrade), and shall extend to the railway property line if this distance exceeds the minimum required by the foregoing formula. (See Fig. 4) If additional tracks are constructed in the future, the casing shall be correspondingly extended.

9. Shut-Off Valves

Where substances are transmitted under pressure an emergency shut-off valve shall be installed within effective distance at the pressure side of the crossing, outside of railway right-of-way.

10. Gravity Sewer Crossings

Casing pipe is not required unless carrier pipe is of a material or grade incapable of withstanding railway loading, in which event the same requirements as specified in Art. 4 will govern, except that corrugated metal pipe of standard construction suitable to withstand railway loading may be used.

11. Location

Pipe lines shall be located, where practicable, to cross tracks at approximately right angles thereto and shall not be placed within a culvert or under railway bridges, except in public thoroughfares when mutually agreed to by the railway company and the owner of the pipe line.

Crossings, where possible, shall be located where the ground surface slopes downward away from the railway.

Longitudinal occupancy of railway right-of-way is highly objectionable and must be avoided where possible.

12. Approval of Plans

Plans containing all pertinent details for the proposed crossing, exclusive of data for seals and vents, shall be submitted to and meet the approval of the chief engineer of the railway company, in the manner as specified under Art. 14, Sec. A. For Flammable Substances.

Report on Assignment 4 (c)

Methods for Installing Culverts Inside of Existing Culverts

A progress report on this assignment was presented last year as information. The present draft has been revised editorially, and is hereby submitted for adoption and inclusion in the Manual, with the recommendation that the assignment be discontinued. It is planned to insert the proposal material in Chapter 1 of the Manual at the end of Part 4—Culverts.

METHODS OF INSTALLING CULVERTS INSIDE EXISTING CULVERTS

When existing drainage structures show signs of weakness or need strengthening to handle heavier loads, it is sometimes possible to salvage the existing material by lining it with new material. Both rigid and flexible-type structures are used for relining. The selection of the shape of the lining and the kind of material to use depend on how much the existing opening can be reduced, the additional strength needed in the lining, the existing foundation conditions, and the space available at the site.

Accurate information on run-off conditions will show how much reduction in waterway opening can be permitted. Some old structures are appreciably oversize; others may require the installation of an additional opening.

1. Survey Existing Structures

A careful survey should be made of the existing structure to determine the exact size and shape. It is necessary to know the exact cross section of the existing opening at all limiting points, the alinement of the structure with respect to its center line, whether projecting parts of the existing structure can be removed, the foundation conditions under the existing structure, and the load carrying capacity of the stream bed. Any old falsework piling, boulders, or ledge rock in the waterway that might interfere with the new material should be reported.

The permissible reduction in opening will determine how tightly the lining material will have to fit the existing structure. Whether the existing structure requires only strengthening or a full load carrying replacement, will define the strength requirements. The space available adjacent to the structure or within it will establish whether the lining material must be designed to erect in place or whether it can be assembled outside and pulled into place.

2. Lining Material

Existing pipes and arches are generally lined with structures of the same shape but smaller in size. Rectangular openings can be lined with round, elliptical or pipe-arch structures, depending on the permissible reduction in opening. It may be necessary to remove projecting portions of the old structure to provide clearance for the lining.

An arch-type lining requires an adequate foundation, particularly if it is to carry a portion of the load on the structure. The new foundation can be benched into or set on the old one, or it may be necessary to provide new footings. Pipe and pipe-arch shapes are self supporting and may overcome inadequate foundations in the existing structure if the stream bed is stable. Occasionally, it may be economical to excavate the existing stream bed below flow line grade so that a pipe can be installed. The stream bed is then allowed to fill up to its natural grade.

3. Installation of Lining

When space is available, the lining structure can be assembled outside of the old culvert and skidded into place. This method requires space to erect at least one unit of the structure at a time and sufficient clearance between the old structure and the lining to permit free movement. Erection by this method is fast and simple because of ease of handling and assembly. A light crane, tractor or jacks will move the lining longitudinally into place.

Where the clearance between the old and new material is small and no space is available at the ends, it is necessary to use a tunnel-liner type of material which permits the entire assembly to be done from inside the structure. Tunnel liners should generally be used when it is necessary to remove an extensive portion of the existing material.

Many lining jobs require not only salvaging the existing structure but also lengthening it to provide for grade changes or additional tracks. In these cases the material will serve as a lining for the old structure and as a new culvert on the projecting ends. One of these conditions may determine the type of material, or it may be possible to vary the material to meet the requirements of each portion. Continuity of the structure is essential, and it is not good practice to combine rigid and flexible material in the same structure.

4. Backfilling

Backfill between the lining and the existing structure is important and must be carefully done. Sand, weak sand-cement grout, a rich grout, or concrete mix can all be used for backfill; each has its advantages. The kind of backfill to use depends on the type of structure, the area to be filled, and to a certain extent on the equipment available.

Sand is used to backfill when the area to be filled is relatively large or where the old structure is weak and a large portion of the load is to be carried by the new material. A sand backfill will allow a flexible lining to adjust to the loads and to work in the way it is designed. It will distribute the load evenly around a rigid structure. It can be blown into place or back-packed by hand where there is sufficient crawl space. A sand backfill requires a closure at the ends of the structure to prevent the loss of the backfill material during the filling and to protect it from erosion by the stream flow. A masonry wall between the structures at each end of the lining is generally used to hold the backfill in place.

A weak sand-cement grout may be used for small openings around flexible or rigid structures. The cement and water serve to lubricate the mix so that it can be pumped into small spaces, and the setting of the cement adds to the stability of the backfill.

A rich grout is used for backfill when the areas are small and where it is desired to strengthen or seal an existing masonry structure. With sufficient pressure the grout can be made to penetrate the joints and cracks in an old masonry structure and add materially to its strength.

A concrete mix is rarely used except where the lining is made to serve essentially as a form and the concrete fill is used as the principal load-carrying medium.

Backfilling is placed through pipes in the opening between the structures, through grout plugs built into the lining material, through pipes extending down through the fill from the top to the opening between the structures, or by side tamping and back packing into the opening when there is enough work space. Often a combination of two or more of the methods is used. The backfill can be forced into place with standard grout pumps or concrete pumps, and it can be placed with air.

It is particularly important that the backfill material be placed so as to be well compacted and completely fill the space between the structures. An opening for the air to escape is required; it may require provision for several openings as the air must be allowed escape to be sure of a complete backfill. Even with care, the first backfilling operation generally does not completely fill the space between the structures. Voids will show due to incomplete filling and from shrinkage in the filling material. The backfilling operation should be repeated until all voids are completely filled.

When the area to be filled is small and the volume of backfill material relatively little, the job can be done without the use of intermediate headers. Headers should be used in long structures and when filling large spaces. They confine the backfilling to small workable areas and permit backfilling to follow closely the erection of the structure.

In filling large areas only a portion of the circumference should be filled at a time. The bottom or invert is filled first, then both of the sides, and finally the top. It may be necessary to install struts to brace the lining against flotation during the backfill.

Lining requires a careful survey of the existing structure and the surrounding conditions, selection of the material best adapted to the conditions, and careful placement of the backfill material. Many old structures have been economically rehabilitated by lining with new culvert material.

Report on Assignment 6

Roadway: Formation and Protection

(a) Roadbed stabilization

(b) Construction and protection of roadbed across reservoir areas; specifications

L. D. Shelkey (chairman, subcommittee), R. H. Beeder, F. N. Beighley, M. G. Counter, W. P. Eshbaugh, R. A. Gravelle, W. T. Johnston, F. R. Naylor, K. W. Schoeneberg, A. W. Schroeder, W. L. Young.

Your committee reports this year on both of its assignments (a) and (b). The report on Assignment (a) is submitted in two parts, designated as Part 1 and Part 2. The entire report is submitted as information.

Part 1 presents pertinent test and construction data, and a comparison of maintenance costs, on three line constructions. Two of the projects had moisture and compaction control but no other soil engineering. The third project was built after a good survey and test program permitted incorporation of soil engineering features. One project having no soil engineering required extreme maintenance, showing an excess of approximately $256,000 in six years. Stabilization is now being considered for the other job.

Part 2 relates the history of an 8-mile construction for the period 1950 to 1954. This construction had controlled compaction and moisture with other soil engineering factors, and its chief difficulty to date has been erosion of cut slopes. This report will serve to show the value of slope erosion control.

Parts 1 and 2 were prepared under committee sponsorship by the research staff of the Engineering Division, AAR. The work is part of the cooperative investigation of the Engineering Division and the Engineering Experiment Station of the University of Illinois, under the direction of G. M. Magee, director of engineering research, AAR. and R. B. Peck, research professor of foundation engineering of the university, and under the supervision of Rockwell Smith, research engineer roadway, who prepared Part 1 of this report.

The report on Assignment 6 (b) is a progress report. Your committee submitted the last of three preliminary reports on this subject in 1950. Now there is presented for consideration and comment a final report on the various phases of this subject, with the intention that it be proposed as Manual material in 1956.

Report on Assignment 6 (a)

Part 1

Soil Engineering in Railroad Construction

In the past the reports under this assignment have dealt mainly with the investigation and stabilization of sections of track in service, but during the course of the investigation into roadbed stabilization, now entering its ninth year, a number of projects have also been observed, particularly new construction, on which fairly complete data concerning construction and maintenance features are available. These include projects on which no provisions pertaining to the soil material were made; projects on which the embankment material was rolled and controlled as to moisture and density, with no special provisions to utilize the other engineering properties of the soil; and still other projects on which the development of full information by means of soil tests, field studies, and such procedures permitted a design for construction best suited to the materials involved. These last projects specified controlled moisture and compaction, together with selection of soil and the use of sub-ballast. These measures are preventative rather than corrective.

A discussion of the construction features involved in three projects of varied types, with a brief resumé of the maintenance history since the start of traffic operations, will disclose the value that may be derived from soil engineering.

Pottsboro–Sadler Relocation

The first of these projects is the Pottsboro–Sadler Revision on the Missouri–Kansas–Texas Railroad in North Texas, designed and built by the U. S. Army Corps of Engineers. This is a 8.8 mile relocation, necessitated by the construction of the dam across the Red River near Dennison, Tex., to replace the lower level original line. The new location crosses the uplands of the region in an area occupied by materials classified pedologically as Wilson Clays, and geologically as Eagle Ford Shale. The Wilson Clays are the soils developed from the clayey shale parent material. Cuts range up to 30 ft in depth and fills up to 35 ft in height. This rather heavy grading resulted in the use of considerable quantities of the shale in the roadbed. The shale slakes rapidly on exposure to air.

Specifications for the grading called for compaction by sheepfoot roller in layers not greater than 8 in. in thickness before compaction; side dumping was prohibited. Construction was by layers over the full width of the embankment. The soil material was to contain the amount of moisture required for maximum compaction (Standard AASHO) as nearly as practicable, and the moisture content was to be uniform throughout the layers. Where the material was too wet to permit the securing of the desired compaction it was specified that rolling and all work on that section be delayed until the material reached the required moisture content. (On this particular job, because of the high temperatures and winds during construction, it was necessary to add considerable water to permit proper densification). The specification also required that for soil having a maximum dry density, as determined by laboratory tests, of less than 115 lb per cu ft, the compaction should be a minimum of 95 percent of this laboratory density. For soils with densities of 115 lb per cu ft and over the specified minimum compaction was 90 percent.

It is the opinion of observers on the construction work that these specifications were fully conformed with, and tests also indicated that moisture and compaction were fully adequate. Table 1 gives the results of a few tests during construction.

A sub-ballast of soft limestone material to a depth of 10 in was spread across the top of the grade by trucks. This material was placed in two 5-in lifts and dressed to

TABLE 1—RESULTS OF SOILS TESTS ON RELOCATION OF M–K–T RAILWAY, POTTSBORO TO SADLER, TEX.

Sample No.	Date Sampled	Type of Material	Location	Soil Constituents, Percent: Sand	Silt	Clay	Results of Std AASHO Compaction Tests: Maximum Dry Weight lb/cu ft	Optimum Water Content, %	Results of Field Density Tests: Dry Weight lb/cu ft	Water Content %	Percent Compaction
1	11-21-42	Borrow	85+75	52	22	26	109.7	16.8			
2	12-1-42	Borrow	94+00	18	82 (2)	(2)	105.8	19.2			
3	12-1-42	Borrow Pit	75+00 Depth 3.0′	11	31	58	82.0	36.2			
4	12-12-42	Borrow Pit	101+00 Depth 2.0′	35	24	11	102.0	18.4			
5	12-12-42	Borrow Pit	28+00 Depth 6.0′	15	85 (2)	(2)	86.2	30.2			
7	1-11-43	Borrow Pit	192+00 Depth 4′-7′	16	31	53	86.4	32.4			
8	1-11-43	Fill	206+00						94.5	27.7	109.2
9	1-14-43	Fill	224+00	24	86 (2)	(2)	82.8	33.0			
10	1-14-43	Fill	224+00						78.6	38.5	95.0
11	1-23-43	Borrow Pit	109+00 Depth 0′-8′	37	32	31	108.0	18.2			
12	1-23-43	Fill	148+00						110.3	14.2	102.2
13	2-12-43	Cut	367+00 Depth 4′-16′	36	32	32	107.8	19.0			
14	2-12-43	Fill	367+00						113.7	17.2	105.2
15	2-16-43	Fill	357+00	38	34	28	112.9	16.8			
16	2-16-43	Fill	357+00						105.9	18.4	93.9
17		Fill	446+00	29	38	33	100.4	22.6			
18		Fill	446+00						98.4	21.5	97.9

Notes: 1. Definition of soil sizes: Sand, larger than 0.05 mm Silt, 0.05 mm to 0.005 mm Clay, smaller than 0.005 mm
2. Silt and clay not separated—value shown for "Silt" represents combined silt and clay.
3. No test results pertaining to Sample No. 6 were found.
4. Blank spaces (dashed) indicate no data were found.

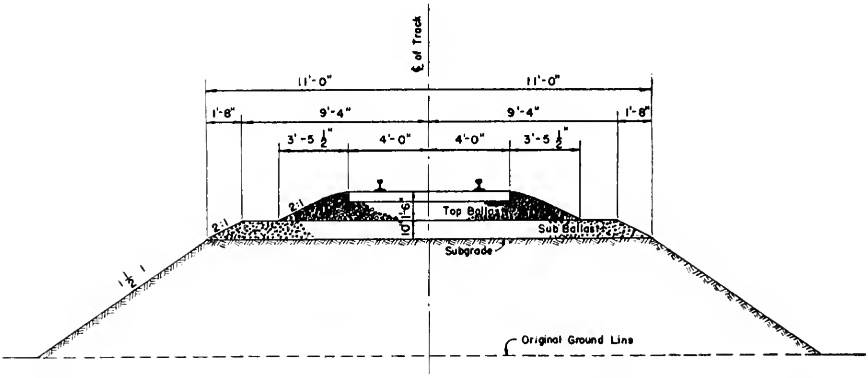


Fig. 1—Typical embankment section, M–K–T Denison Dam relocation.

section. The top ballast was crushed rock to a depth of 1 ft 6 in below base of rail. Typical sections, including both grading and ballast features, are shown in Fig. 1.

The project was put in service in 1944. Very shortly thereafter maintenance troubles became evident. Fill slopes started to slide, in some cases affecting the track, as did also several cut slopes (Fig. 2). Most of the larger fill slopes required flattening. The main difficulty, however, was in keeping the track alined and surfaced because of the development of ballast pockets. These pockets developed at a very rapid rate. In 1948, four years after the start of operation, many of these pockets had developed to a depth of 6 ft, and in one or two cases pockets 9 ft in depth were noted.

After less than six months in service, stabilization of this roadbed was started by means of driving vertical ties and poles near the ends of the cross ties. Before the end of 1945, 31,179 track feet had been so treated at a cost of almost $36,000. In 1948 additional piles were driven in some of the higher fills to control sliding, at a cost of $32,000, and from November 1949 to March 1951 expenditures amounting to $77,000 were made

Fig. 2—Pottsboro–Sadler revision, slides in cut slopes, 1948.

for stabilization of 27,290 track feet by pressure grouting. In 1948 a surfacing was required at a cost of $8000.

This record, from 1945 through 1950, showed the above items as extraordinary maintenance amounting to approximately $153,000. During this period routine maintenance expenditures for labor and ballast were approximately $120,000. This represents an average expenditure per year of $25,500 for extraordinary maintenance and $20,000 per year for routine maintenance, or a combined total of $45,000 on 8.8 miles of track—a cost of $5170 per mile per year. Following the completion of most of the stabilization, a record is available for the years 1951 and 1952 showing an average maintenance cost for labor of $2800 per year, or $318 per mile per year—a saving of approximately $4850 per year per mile.

These figures indicate that considerable value was received from stabilization, but emphasis should be placed on the causes of the abnormally high maintenance and on stabilization costs associated with a new facility built by the accepted standards of the day and receiving excellent inspection. From the record it is apparent that the design did not include consideration of some important features inherent in the project.

Since 1948 a number of inspections and considerable testing have been carried out on the materials encountered. It was ascertained that the soils and shales involved are very highly plastic, with liquid limits of such magnitude that similar material is often excluded in grading specifications. On this particular project the avoidance of such material would have been impracticable, but it does appear possible that some additional construction features could have been devised to prevent the development of instability.

To accomplish this purpose a full knowledge of the properties of the soil material would be necessary. Laboratory tests, which were later run on soil samples taken from the subgrade, disclosed the presence of a considerable portion of a montmorillonite-type clay mineral. This is the mineral usually associated with swelling clays. The tests showed that through a normal range of moisture a swelling of 23 percent was possible. It was established in previous reports that the presence of this type of material was probably responsible for the action of the subgrade (See AREA Proceedings, Vol. 51, 1950, page 719). Further tests on this material, however, indicated that if the soil were confined under pressures of 300 to 400 lb per sq ft the swelling could be reduced to 3 percent or less. Such pressure is the equivalent of approximately 3 to 4 ft of overburden. It is very possible that by capping the clays to this depth with material of lower plasticity and favorable volume change characteristics, the maintenance could have been greatly reduced.

Fort Gibson Dam Relocation

A second project on the same railroad has demonstrated the benefits that can be obtained from soil control and selection. This is the Fort Gibson Dam relocation between Wagoner and Pryor, Okla., also designed and built by the Corps of Engineers, U. S. Army. It consists of three sections at Brush Creek, Choteau Creek, and Flat Rock Creek, aggregating about 8.2 miles. This relocation has a maximum fill of approximately 30 ft, with low cuts. The majority of the embankment material was obtained from borrow pits adjacent to the right-of-way.

Because of the poor maintenance showing of the Pottsboro–Sadler revision the railroad required a soil survey of the material to be involved in the construction of this second project. Table 2 shows test data, including that for swelling tests, on a number of samples. Except for the top horizons, the soils are clays of high plasticity. A mineralogical analysis showed the presence of swelling clay minerals in lesser amount than in the soils of the Texas project. These results, however, together with the results of the

TABLE 2—M-K-T RAILWAY, FORT GIBSON RELOCATION—SUPPLEMENTARY TESTS

Sample	*Depth, Ft*	*Liquid Limit %*	*Plastic Limit %*	*Swell %*		*Initial Water Content, Swell Tests*		*Final Water Content, Swell Tests*	
				Test 1	*Test 2*	*Test 1*	*Test 2*	*Test 1*	*Test 2*
1	0.3–0.7	31.5	17.0	0.3[1]	1.0	29.4	16.9	......	17.7
2	0.7–1.3	33.8	18.5	1.45[1]	......	17.4	......	18.1	......
3	1.3–1.9	63.7	17.9	10.9[1]	......	20.6	......	30.0	......
4	1.9–2.5	66.3	19.2	11.5[2]	......	23.1	......	30.6	......
5	2.5–3.4	61.7	17.2	14.2[1]	......	16.5	......	38.5	......
6	3.4–4.3	61.6	21.1	22.6[2]	......	20.3	......	34.0	......
7	4.3–5.0	63.5	20.0	12.0[3]	18.5	22.7	15.8	34.3	31.0

[1] Air dried and pulverized before compaction.
[2] Dried to initial water content, not pulverized before compaction.
[3] Air dried, not pulverized before compaction.

Note: Tests at University of Illinois May 9–19, 1952. Samples furnished by USED Flat Rock Creek borrow area.

swelling and the plasticity tests, indicated a soil of doubtful quality for use in railroad subgrades. More complete swelling tests indicated that a pressure of 300 lb per sq ft would reduce the swelling features to a safe extent. To prevent all swelling, pressures up to 1300 lb per sq ft would be required. It was estimated that with added protection from surface water an average load of 300 to 400 lb per sq ft would be adequate.

To insure this, specifications were prepared designating that the upper 3 ft of the fills should be constructed with selected soil. This material was specified to have a liquid limit not exceeding 35 percent, and a plasticity index not exceeding 12. For cuts and fills under 3 ft in height the depth of selected soil was specified as 2 ft. Typical sections for fills and cuts are shown in Figs. 3 and 4.

As also shown by Fig. 3, sub-ballast 1 ft in depth, consisting of limestone screenings, was placed on the prepared subgrade. The specifications and gradation of a field sample are as follows:

	Specifications, Percent	*Sample, Percent*
Pass ½" Sieve	100	100
Pass No. 4 Sieve	70–100	96
Pass No. 10 Sieve	30–70	58
Pass No. 30 Sieve	20–45	33
Pass No. 200 Sieve	5–20	12.5

This material was truck hauled, placed in two layers and shaped to sections prior to placement of the ties. Top ballast consisted of 1½ ft of crushed chat, maximum size of 1½ in below base of rail.

Very close control was exercised during construction. The grading was extended the full width of the embankment in layers not exceeding 8 in loose thickness. Where required, water was added to assist in the compaction of the material to maximum density, as determined by compaction tests. Table 3 shows pertinent information on the maximum density and the density actually obtained during construction. A minimum of 90 percent of the laboratory density was required.

A complete record of density determinations is available showing the very excellent control exercised. Many sections on fills failed to meet specifications for density and were reworked. During the placement of the selected soils, the dry weather conditions forced the addition of large quantities of water to obtain the specified compaction.

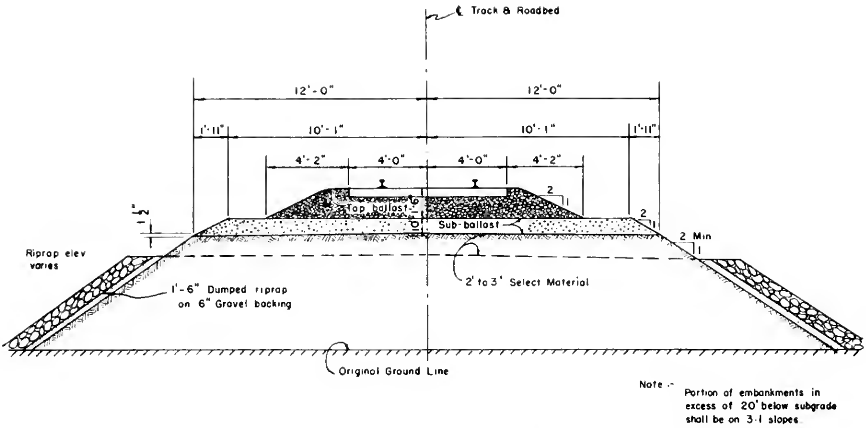


Fig. 3—Typical embankment section, M-K-T Fort Gibson Reservoir relocation.

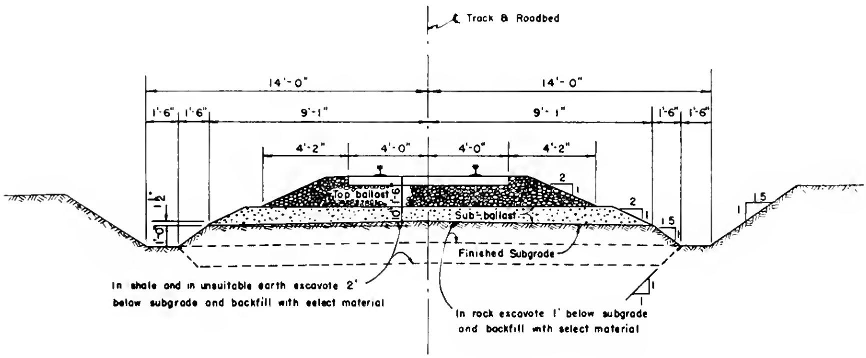


Fig. 4—Typical cut section, M-K-T Fort Gibson Reservoir relocation.

TABLE 3—M-K-T RAILWAY—CONSTRUCTION SOIL TESTS, FORT GIBSON RELOCATION

Sample No.	*Location*	*Soil Type*	*Field Density and Lb/Cu Ft. Dry Weight*	*Moisture %*	*Standard Lb/Cu Ft*	*Moisture %*	*Percent Compaction*	*Percent Required*
371	Flat Rock	Clay	92.0	19.9	99.6	21.1	92.4	90
402	Flat Rock	Clay	100.6	21.3	101.7	22.1	98.9	90
439	Flat Rock	Clay	98.4	22.8	101.7	22.1	96.7	90
443	Brush Creek	Clay	95.6	23.3	96.8	22.0	98.7	90
384	Brush Creek	Clay	98.5	23.3	102.6	21.7	96.0	90
427	Brush Creek	Clay	101.3	17.4	106.8	18.1	94.8	90
166	Choteau Creek	Clay	99.7	21.0	101.5	21.6	98.2	90
102	Choteau Creek	Clay	91.2	26.7	94.2	24.9	96.8	90
162	Choteau Creek	Clay	104.3	14.6	108.2	15.4	96.3	90

TABLE 4—M-K-T RAILWAY—FORT GIBSON RELOCATION, SELECTED SOIL TESTS

Sample	Location	Liquid Limit %	Plastic Limit %	Field Density and Lb/Cu Ft	Moisture %	Standard Lb/Cu Ft	Moisture %	Percent Compaction	Percent Required
486	Flat Rock	28.0	22.0	105.4	15.4	110.0	15.7	95.8	90
496	Flat Rock	23.6	17.8	103.0	15.9	110.0	15.7	93.6	90
504	Flat Rock	29.5	22.5	96.2	16.9	105.6	15.7	91.1	90
475	Brush Creek	31.5	11.7	100.1	16.9	105.6	15.7	94.7	90
600	Brush Creek	32.0	23.0	95.4	17.7	102.2	18.2	93.3	90
570	Brush Creek	33.0	23.2	97.4	18.7	106.2	18.1	91.7	90
545	Choteau Creek	26.0	21.0	107.0	15.8	110.0	15.7	97.3	90
562	Choteau Creek	31.5	22.0	98.0	17.9	106.5	17.1	92.0	90
528	Choteau Creek	25.5	20.0	98.6	19.2	106.5	17.1	92.3	90

To hold additional construction costs at a practical minimum, a search was made for acceptable selected material in the vicinity of the realinement. The topsoils available to a depth of about 15 in over the clay borrow pits showed plasticity and swelling characteristics sufficiently favorable for use as selected material and were so designated. The various test data for this material are shown in Table 4. To obtain this material it was necessary to strip the pits and stockpile; this resulted in some additional cost because of the second handling required. At 60 cents per cu yd the total additional cost for the project is $76,200.

The first section of the project went into operation in the summer of 1953; the other two later in the year; but by November 1954 all had been in service over a year. From inspections and reports from the railroad, maintenance on this relocation has been limited to spot work. In general, the maintenance in excess of that required for adjacent track would not be over 10 percent. Special speed restrictions were in effect at the start

Fig. 5—Fort Gibson revision, open cracks developed during dry season.

of operation for two weeks, at the end of which time they were raised for another two weeks and then removed entirely.

Because of the continuous dry weather and the shrinkage and swelling characteristics of the clay, several longitudinal cracks have opened to a width of 2 or 3 in near the shoulder line (Fig. 5). Heavy rains or a prolonged wet period would possibly affect these areas adversely and result in some slips or sloughing of the slopes. Indications at present are that this will not affect the track as these cracks are well outside the ballast line. Such occurrences will require additional maintenance to restore shoulder and width of grade.

The comparison of this project with the Pottsboro–Sadler revision as regards maintenance is very striking. If the present performance continues, the additional cost of the soil engineering features have been repaid many fold.

KO&G Relocation

A further illustration of the possible value of soil engineering can be cited in this same vicinity. The Kansas, Oklahoma & Gulf Railroad was relocated approximately 15 miles for the same reason; this relocation was built by the Corps of Engineers and incorporated the same procedures as to compaction and moisture control as on the Katy Railroad. However, no soil tests were made independently, and no selection of materials was attempted. A foot of chat ballast, ½ in maximum size, was placed under the ties after the track was laid. No sub-ballast was specified.

This project has been in service for over two years and maintenance expenditures have been practically double that for adjacent track sections. In addition, considerable ballast material has been required, and slow orders of 20 to 25 mph are still in effect over portions of the revision.

Pockets are developing at a rapid rate as evidenced by squeezes at the center line, and particularly beyond the end of the ties. It is estimated at present that 25,000 ft, practically 5 miles out of 15, are adversely affected. To restore normal traffic conditions on this revision a considerable program of stabilization, probably by pole driving and pressure grouting, is contemplated.

The above projects have been selected for this report as most striking examples of the value of soil engineering in railroad construction. In many cases and under many conditions the use of moisture and density control alone will produce acceptable sub-

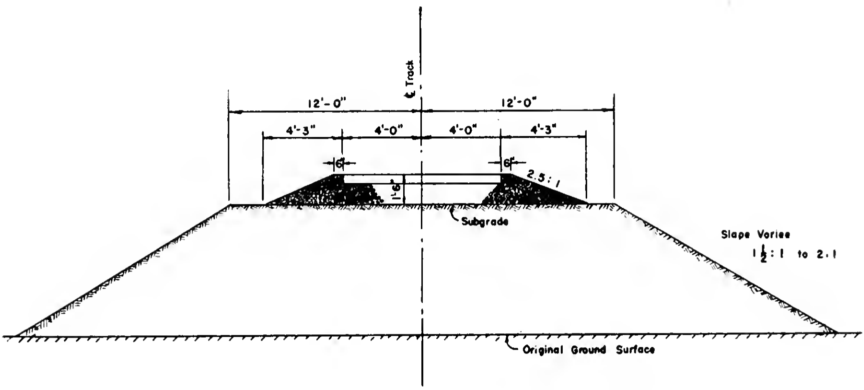


Fig. 6—Typical embankment section, KO&G Fort Gibson Reservoir relocation.

grades (See Part 2 of this report). This is dependent upon soil characteristics to a very great extent. For most construction projects the cost of soil investigation is relatively low and may yield big dividends through maintenance savings. Selection of soil normally encountered in grading operations can often produce great benefits at very little extra construction cost. In addition to the selection of material for the roadbed, the stockpiling and use of the topsoil for surfacing cut and fill slopes can also be of great benefit in the promotion of vegetation and the reduction of slope erosion and ditch cleaning costs.

Part 2

Illinois Central Relocation at Grenada Reservoir

By Ralph B. Peck

Research Professor of Foundation Engineering, University of Illinois

Description

The construction of Grenada Dam across the Yalobusha River in north central Mississippi required the relocation of about 11.5 miles of a single-track line of the Illinois Central. The design for the relocation was made by the U. S. Army, Corps of Engineers. Exploratory auger borings and 2-in undisturbed sample borings were made by the Army Engineers at intervals of about 1000 ft. Soil tests were made by the U. S. Army, Corps of Engineers, prior to construction, and additional tests were made during and after construction by the railroad, the AAR, and the University of Illinois.

Construction was carried out in 1949 and 1950 by contract under the supervision of the Illinois Central. Several inspections were made by the research personnel during and after construction.

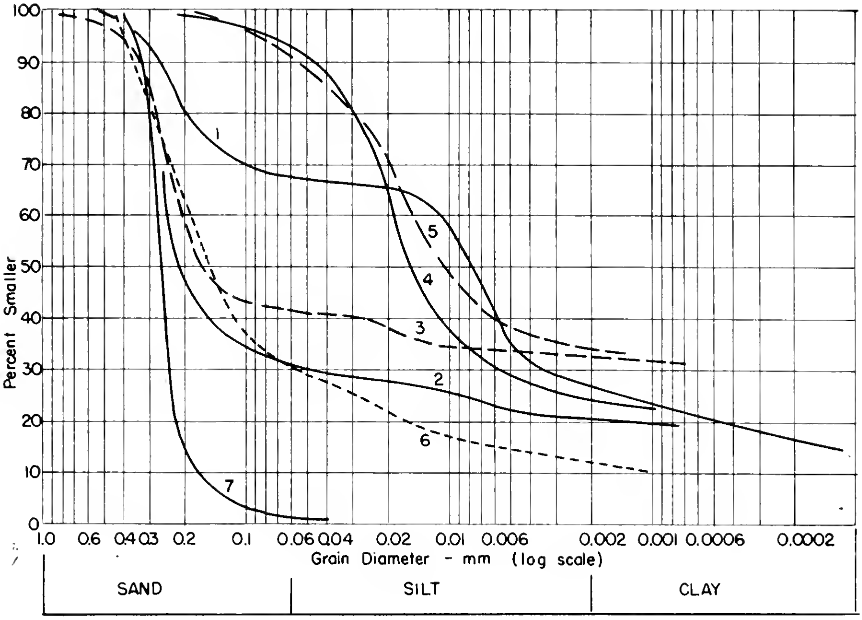
The new line involves a number of long fills approximately 20 ft in height across alluvial bottomland, and several cuts through ridges of soft sandstone and shale of tertiary age. Except for one cut of 45 ft, most of the cuts do not exceed 35 ft in depth.

The design and construction were in accordance with modern recommended practices, and the work was executed under careful inspection and supervision. Therefore, the behavior of the project after completion has been systematically observed to learn if beneficial results have been obtained by the procedures used. Although traffic is relatively light, sufficient information has now accumulated after four years of service to warrant an account of the project.

Fills

General. The subsoils of most of the fills appear to consist of an erratic combination of alluvial deposits containing primarily silt, clayey silts, and sandy silt, with a few inclusions of clay and sand. Borings, extending to depths of as much as 50 ft below the bases of the fills, consistently encountered such materials. Some organic matter was encountered, including a few buried trees. The materials were saturated. Since all the fill materials were at least moderately pervious and no extensive deposits of plastic clay were encountered, no difficulties were anticipated or experienced with respect to the supporting capacity of the underlying material.

Fill Materials. Most of the fill materials were taken from adjacent cut areas or from borrow areas above the bottomland. They consisted primarily of silt, sandy silt, and clayey silt. Typical properties of the various fill materials are shown in Fig. 1. The



No.	Classification	Liquid Limit	Plastic Limit	Plasticity Index	Maximum Dry Density lb/ft³	Optimum Moisture
1	Sandy silt	23.0	15.2	7.8	106.0	17.0
2	Clay sand	25.1	15.4	9.7	117.5	13.3
3	Sandy clay	34.5	14.1	20.4		
4	Clay silt	41.4	22.9	18.5	107.0	16.4
5	Silty clay	55.7	21.5	34.2	102.1	19.0
6	Silty sand	17.4	–	NP	117.5	12.6
7	Sand	–	–	NP	102.0	11.0

Fig. 1—Characteristics of fill materials.

curves of grain size, the classification, and the liquid and plastic limit values, have been determined for representative samples of the various materials. Similarly, the values of maximum dry density and optimum moisture were determined by means of standard Proctor tests on representative materials of the same classifications. However, the samples used for the density and optimum moisture determinations were not the same as those for the classification tests.

The natural moisture content of the materials in the borrow pits was commonly approximately equal to the optimum moisture content. Therefore, except during rainy seasons, little difficulty was experienced in placement of the fill.

The excavation was done largely with scrapers or carryalls that deposited the soil in thin lifts having a compacted thickness of 6 in. Compaction was obtained by sheep-foot rollers loaded to exert a pressure of about 400 lb per sq in on the tamping feet. Furthermore, the path of the hauling vehicles was varied over the top of the embankment. Water content control was practiced. Each lift was subjected to moisture content and density determinations in the field. Field compaction was generally in the range of 95 to 100 percent.

In a few localities a silty clay shale was encountered. This material had a dry density of about 60 lb per cu ft, a natural water content of about 44 percent, and a liquid limit of about 90 percent. Therefore, it was considered unsuitable for filling material and was not incorporated in the embankment.

Behavior. In general, the behavior of the fill sections has been satisfactory. No instability of the base of the embankment has occurred. The fills themselves have also been stable. Subsidence of the alluvial material beneath the fills was anticipated, and was measured by the installation of eight settlement plates at various locations where the fill had the maximum height of about 20 ft. The maximum settlements of these plates has been about 0.6 ft. Most of this subsidence occurred in the first two years.

The original top width of the fill was 22 to 24 ft, and the side slopes were 1½ horizontal to 1 vertical. Because of the generally silty nature of the fill and the intense rainfall that occurs at certain times of the year, gullying of the slopes has been pronounced on several of the fills. The gullying has been of little consequence where a growth of vegetation has been obtained, but on bare slopes the fills have locally been cut back close to the ends of the ties and have required building out.

Cuts

Construction. Most of the cuts, particularly the shallower ones, were excavated through relatively soft thin-bedded shales. In general, the cuts had a bottom width of 40 ft and side slopes of 1½ horizontal to 1 vertical. Although no slope protection was provided for the cuts in shale, no difficulties were encountered during construction, and no serious erosion has occurred since that time. These cuts appear to be entirely stable (See Fig. 2).

Several other cuts were excavated in slightly cohesive sand. The degree of cementation was hardly sufficient to justify terming the material sandstone. One of these cuts, known as the Torrance cut, was the deepest on the line and led to considerable difficulty both during and after construction.

Fig. 2—1½:1 cut slopes in sandy clay and soft shale.

The north portion of this cut had a length of about 500 ft and a depth, according to the original plans, of about 45 ft. In the excavation free water was encountered about 5 ft above final grade. Attempts to dig ditches along the sides of the cuts were not successful. partly because the sand was in a quick condition, and partly because daily rains washed silt and sands down from the slope. The difficulties indicated the necessity of predrainage of the area before construction, or of revising the grade. The latter was adopted, and the depth of the cut was reduced to 40 ft, but subdrainage was later installed also. The side slopes were established at 1½ horizontal to 1 vertical, and a 10-ft, nearly horizontal, bench was established at a height of about 10 ft above the base of rail. A second bench was established of the same width about 15 ft above the first. The purpose of the benches was to provide berms for collecting water descending the slopes in order to prevent erosion. After the grade revision, and drainage, the cut was completed with only minor difficulty.

Behavior. During the first wet season after construction of the cut, extensive gullying of the slopes occurred. Water cut through the benches in various places to the extent that the contours of the slopes were seriously modified and sand accumulated in the ditches beside the tracks to such an extent that the ballast section was locally covered. As a consequence, the slopes were resurfaced in 1950 to uniform slopes without benches of 3 horizontal to 1 vertical. A serious effort was made to establish a growth of grass by means of sodding. The growth of vegetation was relatively successful, and a satisfactory stand of grass was obtained.

Nevertheless, the grass was not adequate to prevent erosion. Gullies began to form, working upward from the ditches into the sand and creating, on a miniature scale, ver-

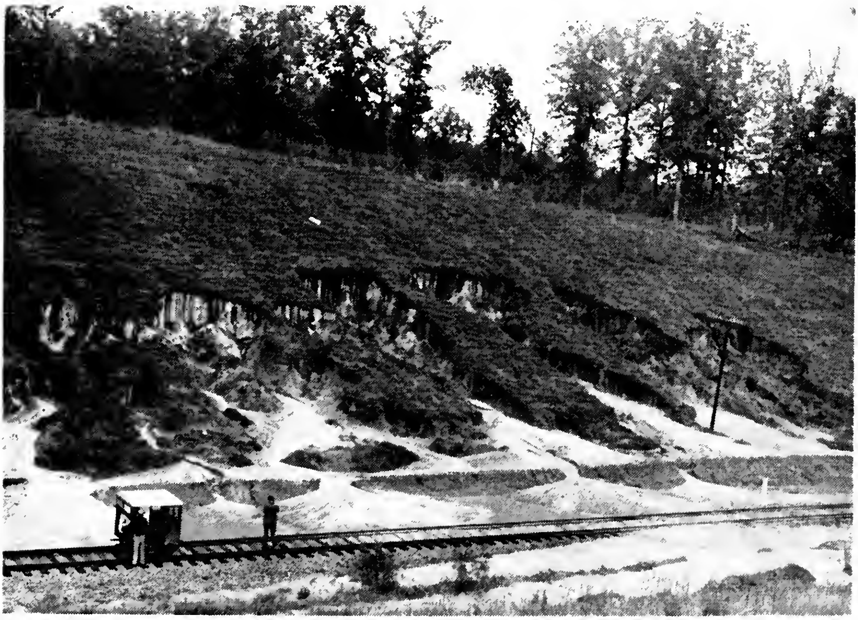


Fig. 3—Slope erosion in sandy cut.

tical columns and pinnicles similar to badland topography. Efforts to fill the gullies with brush to prevent the erosion were not successful. It appears that the slopes will gradually be eroded from the bottom until they are nearly vertical, and wide flat areas will remain near the elevation of the track. The establishment of drains below ditch level has had considerable success in avoiding general instability of the slope, but has not had any influence on the gullying. (See Fig. 3).

Subgrade

The subgrade of the revision was capped with a sand-clay-gravel sub-ballast. Throughout the revision the subgrade has performed satisfactorily, with the exception of five or six spots where ballast pockets have developed. It appears that the sub-ballast was hauled onto the grade when a few of these areas were still soft. It is probable that enough displacement occurred at that time to permit the collecting of water, and that development of pockets has since been progressive.

Some of the material below the sub-ballast was of quite plastic nature. At one place where a major pushout occurred, the soil was found to have a liquid limit of about 80 percent and a plastic limit of about 37 percent. The material was found to consist of about 50 percent montmorillonite, with the remaining 50 percent being composed of about equal amounts of illite, kaolinite and quartz. Calcium was the dominate exchangeable base in the montmorillonite. The presence of such highly plastic materials unquestionably favored the development of soft spots.

The general effectiveness of the sub-ballast seems to be demonstrated by the small number of ballast pockets that have formed, considering the plastic nature of some of the subgrade material.

Conclusion

In general, the construction of the revision has been highly satisfactory. The compacted fill has been entirely stable, and the construction was carried out with little difficulty.

The most troublesome aspect of the revision to date has been the erosion of the cut slopes in slightly cohesive sand. The slopes now being assumed in the cuts, as a result of natural forces, would seem to indicate that such material might preferably be excavated on nearly vertical faces to present as small an area as possible for the collection of precipitation.

Report on Assignment 6 (b)

Construction and Protection of Roadbed Across Reservoir Areas: Specifications

The construction and protection of roadbed across reservoir areas present many different problems and an analysis of these problems can best be made by subdividing the subject into four phases, as follows:

1. Determination of wave heights.
2. Determination of wave forces.
3. Construction of embankment and roadbed.
4. Construction of embankment protection.

These phases can now be handled as individual items, and methods outlined for each separately.

A. DETERMINATION OF WAVE HEIGHTS

The study of wave action is not new. Engineers and mathematicians have struggled with this problem since the time of Leonardo de Vinci, and as early as 1802 Franz V. Gerstner obtained an exact solution of the equation of motion for deep water waves. Through subsequent years other investigators have studied the problem from which the well known empirical formulas of Stevenson, Golliard, Molitor, Creager and others have evolved.

However, the accuracy of the measuring equipment of the early investigators was not adequate and the manner in which the data were obtained did not permit accurate determination of wave heights or the magnitude and distribution of pressures, and there is little conclusive evidence confirming the accuracy of the various empirical formulas when applied to reservoir situations.

In 1942, H. V. Sverdrup and W. H. Munk of the Scripps Institution of Oceanography were commissioned by the U. S. Air Force to study forecasts of sea and swell in connection with the planned invasion of North Africa. Their investigations resulted in expressions for wave height and period in terms of wind velocity, wind duration and fetch, from which accurate forecasts can be made.

The original investigations of Sverdrup and Munk applied only to deep water ocean waves, and are of questionable value when applied to small bodies of water.

The University of California, under the direction of C. L. Bretschneider, studied the problem of wave action at Clear Lake and Abbots Lagoon in California, and Bretschneider has expanded the original Sverdrup and Munk relationships to apply to inland lakes and reservoirs.

The Bretschneider expression for the significant wave height in deep water is:

$$H = 0.045\ UF^{0.5}$$

in which H = Significant wave height, from trough to crest, in feet.
F = Fetch, or distance over which the wind blows, in miles.
U = Velocity of wind, in miles per hour.

The expression for the significant wave height in shallow water is:

$$H = 0.134\ U^{0.5}\ d^{0.75}$$

in which H and U are as stated above, and d is the depth of the water in feet.

For statistical purposes, the significant wave height is defined as the average of the highest one-third of the waves.

From an analysis of wave records at three locations along the California coast, it was found that the average value of the daily maximum wave height was 1.87 greater than the significant wave height. Later observations taken at Texoma Lake on the Red River, in Texas, and at Lake Okeechobee, in Florida, confirms that average value. Therefore, the height of the "design" wave shall be taken as 1.87 times the significant wave height.

For a given fetch there exists a minimum duration for which the fetch and duration curves give the same wave height. If the duration is less than this minimum, the wave heights are determined from the duration curve; if the duration is greater than this minimum, the wave heights are determined from the fetch curve.

The expression for duration is:

A

$$D = \frac{2.45\ F^{0.778}}{U^{0.566}}$$

in which F and U are as set forth above, and
D is in hours.

The solutions are given in Fig. 1.

Knowing the wind velocity and duration, and fetch length, enter the left of Fig. 1 and proceed toward the right along the wind velocity horizontal until the duration or fetch length is reached first, then read off the appropriate significant wave height.

As the wave height given by Fig. 1 is the height from trough to crest, and as the orbit of the wave extends from one-fourth to one-third of the total height below still water level, the height above still water level shall be taken as 0.75 of the total height.

Still water elevation shall be determined as follows:

(a) For flood control reservoirs having uncontrolled spillways, the still water elevation shall be taken as the elevation produced at the site by a flood crest reaching the elevation of the spillway crest.

(b) For multi-purpose reservoirs having controlled spillways, the still water elevation shall be taken at the elevation produced at the site by a flood crest reaching the top of the spillway gates.

All available synoptic weather maps and other pertinent data for the area should be studied and the wind direction, probable maximum velocity, duration and fetch determined.

B. DETERMINATION OF WAVE FORCES

As with the study of wave heights and wave action, the forces on shore structures caused by breaking and non-breaking waves have been a subject of study for years.

The better known works are those of Gerstner, de St. Venant, Flamant, Lira, d'Aurie, Sainflou, Gourret and Iribarren.

For a complete discussion and comparison of the results of these theories, reference is made to "Wave Forces on Breakwaters", by Robert T. Hudson, Transactions of the American Society of Civil Engineers, Vol. 118, page 653.

The only extensive studies of this problem which have resulted in generalized criteria applicable to many situations were made by Ramon Iribarren Cavanilles. The original Iribarren formula, which fixes the slope and size of stone necessary to resist wave action, is in metric form. Converted to English units it becomes:

$$W = \frac{C\ (0.305\ H)^3 d}{(\cos a - \sin a)^3 (0.016d - 1)^3}$$

in which W = Weight of individual stones in pounds.
C = Coefficient with values of 0.529 to 0.670.
H = Design wave height in feet.
a = Angle of slope with the horizontal.
d = Density, or weight of stone per cubic foot.

The coefficient 0.529 is satisfactory for riprap dumped from trucks and built up in layers from toe to slope.

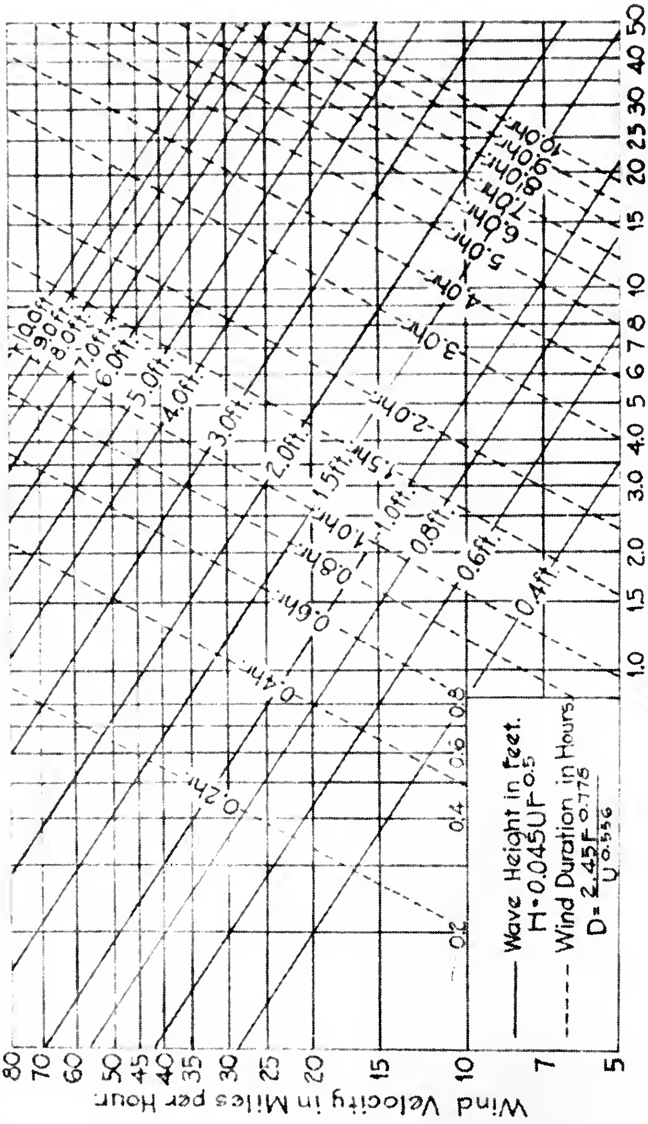


FIG.1. WAVE HEIGHT AS A FUNCTION OF WIND VELOCITY AND FETCH-FOR SHORT FETCHES.

NOTE: This diagram yields significant wave heights, viz. average of highest $\frac{1}{3}$rd of waves. Maximum wave height = 1.87 x significant wave height.

C. CONSTRUCTION OF EMBANKMENT AND ROADBED

The embankment shall be constructed in accordance with the provisions of the "Specifications for the Formation of the Roadway", Chapter 1, Part 1 of the AREA Manual.

That portion of the embankment which will be submerged shall have side slopes not less than 3 to 1, and no material shall be used in the embankment which has a liquid limit in excess of 60 as determined in accordance with ASTM Designation D 423–39, Standard Method of Test for Liquid Limit of Soils.

The width of the roadbed, side slopes, prepared ballast and subballast shall be in accordance with the standards of the Railway Company.

D. CONSTRUCTION OF EMBANKMENT PROTECTION

1. General

The protection shall consist of dumped riprap of thickness as hereinafter specified, placed on a filter blanket of gravel or crushed rock. The protective covering shall extend from the natural ground surface at the toe of slope to heights as specified, but shall not be less than 4.0 ft above still water elevation.

2. Freeboard

The riprap protection shall extend to a vertical height above still water elevation equal to 0.75 of the maximum design wave height, plus a distance to provide for run-up equal to 0.40 of the wave height.

3. Filter Blanket

A filter blanket composed of gravel or crushed rock not less than 4 in and not more than 12 in. in thickness shall be placed on the embankment slope to form a backing for the riprap protection. The filter material shall be reasonably well graded within the following limits:

Sieve Size	*Percent by Weight Passing*
3″	100
1½″	40–60
¾″	0–10

4. Riprap

Riprap stone shall meet the quality requirement of the Specifications for Riprap Stone in Chapter 1, Part 1 of the AREA Manual. Stone equal to or larger than the theoretical weight computed by the Iribarren formula, with a few larger stones up to twice the weight of the theoretical size, shall make up 50 percent of the rock in weight.

The gradation of the lower 50 percent shall be selected to satisfy the requirements between the riprap and filter blanket. Within these limits the gradation from largest to smallest sizes shall be quarry run.

5. Littoral Currents

Where waves will impinge against the embankment at an oblique angle and then break, a longshore component of the breaker velocity will result. Consequently, a littoral or longshore current is established in the direction of this component. It is this littoral current, combined with the agitating action of the breaking waves, that is the primary factor in causing displacement of the riprap slope protection.

For a long straight beach the strength of the littoral current has been found by laboratory studies, supplemented by field observations, to be:

$$V = \frac{e}{2}\left[\sqrt{\frac{1 + 3.45\ H_b^{0.5}\ \sin a}{e}} - 1\right]$$

in which $e = \dfrac{2.61\ m\ H_b \cos a}{T(0.024\ C^{-1.51})}$

V = Littoral current in feet per second
m = Average slope of the embankment
H_b = Breaker wave height
a = Breaker angle
T = Wave period in seconds
C = Velocity of deep water waves in feet per second

After determining the deep water wave characteristics for the site, the breaker height and angle can be determined from refraction diagrams constructed to show wave fronts up to the point of breaking. With these variables known, the strength of the littoral current can be calculated and the weight of the stones increased to meet the requirements.

6. Slopes

The side slopes shall range from 2¼ to 1 to 4 to 1, to meet the requirements of the Iribarren formula for wave heights and the available weight of stone.

7. Thickness of Riprap

The thickness of riprap shall conform, in general, to the following minima:

Wave Height in Feet	*Thickness of Riprap in Feet*
Up to 2	2.0
2 to 4	2.5
4 to 8	3.0
Greater than 8	3.5

Report on Assignment 8

Fences

Critical Review of All Methods of Preventing Snow Drifts

H. G. Johnson (chairman, subcommittee), W. G. Dyer, L. V. Johnson, L. R. Shellenbarger, R. C. Young.

Last year your committee presented as information, for the purpose of soliciting comments prior to submission for adoption and inclusion in the Manual, a report, consisting of three parts (see Proceedings, Vol. 55, 1954, pages 655 to 663, incl.):

Part 1—Methods of Protecting Against Drifting Snow and Opening Snow Blockades.
Part 2—Specifications for Wood-Slat Portable Snow Fences.
Part 3—Methods of Protection Against Drifting Sand.

As no comments or criticism have been received by your committee, all of this material is now submitted with the recommendation that it be adopted and published in the Manual.

In placing in the Manual the material on Methods of Protecting Against Drifting Snow and Opening Snow Blockades, it is planned to divide it into two parts, placing that material dealing with Protecting Against Drifting Snow at the end of Part 6—Fencing, of Chapter 1, with the heading "Methods of Protecting the Roadway Against Drifting Snow." The material dealing with Opening Snow Blockades will be included at the end of Part 1—Roadway, of Chapter 1, with the heading "Methods of Opening Snow Blockades."

The Specifications for Wood-Slat Portable Snow Fences will be placed at the end of Part 6—Fencing, of Chapter 1, and that material on Methods of Protecting Against Drifting Sand will be placed in Part 1—Roadway, of Chapter 1, immediately following present material on Roadway Protection.

Report on Assignment 9

Reflectorized Roadway Signs

Collaborating with Committee 9 and the Signal Section, AAR

J. E. Chubb (chairman, subcommittee), M. B. Davis, Paul McKay, J. R. Scofield, J. C. Woods.

Your committee presents the following report as information.

Types of Reflectorized Signs

As an aid in making roadway signs more readily distinguishable at night, the use of reflectorizing materials may be considered desirable. In some locations where roadway signs are used to convey information to the public, as in the case of grade crossing signs, the use of reflectorized signs may also be required by law. This report does not include any recommendations for the use of reflectorizing material for signs, but reference is made to the recommendations contained in the Association Manual, pages 9–2–3 to 9–2–7, incl., pages 9–3–7 to 9–3–13, incl., and 9–4–4, 9–4–5 and 9–M–6, covering its use on roadway signs affecting highway traffic.

There are several different types of reflectorized signs on railways, and this report includes a brief description of each, with some discussion concerning their advantages and disadvantages.

Signs Employing Reflector Buttons

These usually have the letters or other characters used in the sign's message formed by groups or clusters of small reflector buttons, each of which is a reflective unit and is placed on the sign individually. Such buttons are usually made of transparent plastic or glass of a desired color (or without color) in which either the front, or more often the back, side is moulded in a specific shape to give it the desired reflective properties. Included in this type, in addition to the single unit button or "cat-eye", are reflectors which could better be described as discs, usually having a flat front surface instead of the curved front surface of the true button. They are used in a range of sizes from those only a fraction of an inch in diameter to areas several inches in diameter, as in the case of speed limit signs and switch targets. Reflector buttons have the advantage of a very high reflective property because of the precision with which they can be manufactured, and are of a very permanent nature except for actual breakage. A further advantage of individual buttons is that they can be replaced in case of partial breakage or other failure without having to renew the entire sign or area. Breakage is not as likely in plastic as in glass, but the former is much more vulnerable to scratching when harsh materials are used in cleaning. Disadvantages are that the use of buttons do not give a continuous stroke letter or character when seen by reflected light, and the fact that the larger area reflectors invite breakage from vandalism by appearing as a convenient target. Where reflector button-type signs are to be used on signs at highway grade crossings, reference should be made to the AAR Signal Section Manual, Part 43, Specifications 156–49, pages 1 to 4 incl.

Signs Employing Reflectorizing Sheet Materials

These usually have the front surface of the sign, or part of it, covered by one of two types of a thin sheet of reflective material. One type has very small transparent beads partially embedded in a clear plastic sheet base, and the other has the same type beads entirely embedded in the base, both having a highly reflecting material, such as very thin sheet aluminum or metal foil, on the back to give the reflecting property, while the beads control the angle of reflection. The former of these two types of sheet reflective material has no notable advantages over the latter and has several disadvantages. Obviously, its rough surface collects dirt and is difficult to clean, and, in addition, any film of ice or water on the surface changes the reflective index of the beads and greatly reduces the reflective property of the material as long as the film is present. The smooth surface sheet material is not so affected. Probably the most outstanding advantages of these types of material are: (1) The ability to cover part of the sign with colored transparent films or opaque areas so that an unlimited variety of shapes and colors can be obtained at comparatively low cost (the reflective materials can be obtained in any of several bright colors or white, and the transparent overlays in any color, preshaped as letters or other designs); (2) The fact that any desired reflective area of the sign, whether it is the letters, the background, or some other shape, appears as a continuous light in contrast to the reflector button type. Breakage is difficult, although much deformity of the surface can destroy the reflective properties of the damaged area. Where reflectorized sheet material is to be used on the signs of highway crossing signal assemblies, reference should be made to AAR Signal Section Manual, Part 276, Specification 255–51, pages 1 to 5 incl.

Signs Employing a Sprayed On or Directly Applied Reflective Surface

The finished product in this type is very similar to the first of the two reflectorized sheeting types discussed above, the difference lying in the manner of construction. In this type, a binder coat of special material is applied to the sign and, before it dries, very small, specially made, clear beads are sprayed on or otherwise applied to the surface so they are embedded in the binder coat about half their diameters and remain there after the binder coat has dried. These give a reflective property to the sign and the reflected color is the same as the color of the binder coat, usually white. Economy and simplicity of application in the field are advantages of this type. Disadvantages are the same as those discussed for the similar type of reflective sheeting material, and further that unless the beads are skillfully distributed evenly over the surface "streakiness" in the surface will result.

Methods of Reflectorizing Signs

Any discussion of types of reflectorizing materials must of necessity include at least brief information concerning the method of applying the material to the sign, and this has been done to some extent in the preceding descriptions. The following information will complete a general discussion of the several methods. For further details, reference is made to a wealth of information available from the manufacturers of the various types of materials in use.

Small reflector buttons to be installed individually on a wooden sign are made with either a wood screw, nail or bolt extending from the center of the back of the button for either driving or screwing into the wood, or by inserting the bolt through a hole in the sign and fastening with washer and nut. The larger reflector types are held in place in a metal frame, usually made with two or more fins drilled for fastening to a wooden sign by screws, or to a metal sign by bolts or rivets. The reflector–button type sign is also often made by applying manufactured metal letters or characters in which the individual reflectors have been factory installed in the letters or characters. The whole letters or characters, with several buttons in each, are then applied in one operation. Application by bolts, screws or rivets is recommended for this type sign. The use of adhesive material is not considered as satisfactory.

Reflectorizing sheet materials are attached entirely by adhesive bond to the signs and the overlay discussed under this type may be fastened to the front surface of the reflective material at the same time the latter is being bonded to the sign surface, in a one-step process. Reflective sheet materials can be obtained with an adhesive backing for direct application, but such types will not lend themselves uniformly well to surfaces of different characters. The most permanent results can be obtained by shop application with heat and pressure in machines specifically made for the purpose. This latter method results in a practically indestructible bond between the material and the sign backing, withstanding extremes of temperature, weather conditions and rough handling. The economies of such a method depend upon the volume of work to be done. The materials can be applied equally well to metal and wood, and the use of preshaped signs of extruded aluminum for this purpose, especially for highway crossing signs, is growing in popularity because of their lightness, resistance to corrosion, and small maintenance required after erection.

Because of the manner in which application is made, the so-called spray-on reflectorizing materials discussed above lend themselves best to signs made from pressed sheet metal, in which the letters, characters, symbols, and possibly the border, are preshaped in the sheet metal. This permits application of two kinds. In one, the white bonding material is rolled on the sign, which has been painted black, contacting and remaining on only the raised portion. The beads are then applied to the bond, resulting in a reflective white message or pattern on a black background. In the other method, the entire sign is covered with the bonding material and the beads applied, after which a black, opaque paint or special material is rolled over the sign, leaving black letters or design on a white background. This type of reflectorizing can also be applied where surfaces are not embossed by the use of stencils or masks, or by actually painting black over a reflectorized white surface. In all cases, care must be exercised to apply the reflector beads very evenly over the surface to avoid streaks when seen by reflected light.

Report on Assignment 10

Ballast

(a) Tests

(b) Ballasting Practices

(c) Special Types of Ballast

J. P. Datesman (chairman, subcommittee), E. W. Bauman, A. P. Crosley, A. T. Goldbeck, B. W. McCuskey, L. E. Rundell, C. D. Turley, I. N. Vaughn, 3rd, Stanton Walker.

Your committee submits, as information, report under Assignment (a) Tests, in two parts. The first part deals with different sizes of ballast placed for test, and the second presents a further progress report of oscillator ballast tests.

Report on Assignment 10 (a)

Tests

Part 1

Test Installation on Chicago & North Western Railway

In July 1954 a test installation of three different sizes of slag ballast was made by the Chicago and North Western Railway on its north or No. 2 main line, between Maple Park and Cortland, Ill., located approximately 50 miles west of Chicago.

The ballast was placed under new 115-lb rail, and at the location placed the rails laid were pressure welded into lengths of 78 ft and 117 ft.

The three different sizes of ballast placed were AREA Specification No. 3, sizes 2 in to 1 in; AREA No. 4 sizes 1½ in to ¾ in, and AREA No. 5, sizes 1 in to ⅜ in.

The mile post location, together with a screen analysis and Los Angeles abrasion test made at the AAR Research Center, are as follows:

M. P. 50–52

Nominal Size 1½ in–¾ in
Gradation:

Screen Size—In	*Percent Passing*	*Size No. 4 AREA Spec. Percent Passing*
2	100	100
1½	98.4	90–100
*1	12.8	20–55
¾	1.6	0–15
½	0.8	
⅜	0.8	0–5

Los Angeles Abrasion:
Percent Loss—30.7

* Fails gradation specification for this size.

M. P. 52–53

Nominal Size 2 in–1 in
Gradation:

Screen Size—In	*Percent Passing*	*Size No. 3 AREA Spec. Percent Passing*
2½	100	100
2	100	95–100
*1½	31.3	35–70
1	4.5	0–15
¾	3.0	
½	3.0	0–5
⅜	1.8	
No. 4	1.8	

Los Angeles Abrasion:
Percent Loss—29.6

* Fails gradation specification for this size.

M. P. 53–54

Nominal Size 1 in–⅜ in
Gradation:

Screen Size—In	*Percent Passing*	*Size No. 5 AREA Spec. Percent Passing*
1½	100	100
1	100	90–100
¾	93.2	40–75
½	53.3	15–35
⅜	24.0	0–15
No. 4	2.0	0–5

Los Angeles Abrasion:
Percent Loss—36.5

Maintenance costs, together with the service life of the three different sizes of ballast placed, will be made available to the committee by the Railway at yearly intervals.

The following is the second progress report on the oscillator ballast tests now in progress at the Association of American Railroads Research Center. A preliminary report describing the tests was published in the Proceedings, Vol. 54, 1953, page 1140, and the first progress report was published in the Proceedings, Vol. 55, 1954, page 663.

Part 2

Second Progress Report on Research Project on Ballasts

Synopsis

This is the second progress report on oscillator ballast tests now in progress at the Association of American Railroads Research Center. These tests were set up to determine the durability and stability of various types and gradations of ballast materials, with the purpose of obtaining information which will help reduce ballast costs by the rational selection of a material which will produce the best service record from available types and gradations. At the time of this report tests have been completed on four ballasts.

Introduction

The oscillator ballast tests are under committee sponsorship and were started late in 1952. The work is being performed by the research staff of the Engineering Division of the Association of American Railroads, under the general direction of G. M. Magee, director of engineering research, and under the guidance of Rockwell Smith, research engineer roadway. The test installation and methods of test are described in detail in a preliminary report entitled "Research Project on Ballasts", which appears in AREA Proceedings, Vol. 54, 1953, pages 1140–1142.

Discussion

Tests have been completed on four ballast materials. These materials are: (1) crushed limestone, 1½ in–¾ in nominal size; (2) crushed air-cooled blast furnace slag 1½ to ¾ in nominal size; (3) gravel 41–100 percent crushed particles, corresponding to AREA gradation G–3, and (4) chat ballast which has 100 percent passing the 1½-in screen and 12 percent passing a No. 4 screen.

Before each new ballast is tested a representative sample of about 200 lb is selected from the material to be tested and a complete screen analysis is run on this sample to determine the original gradation of the material. The ballast to be tested is then placed in the 5 ft wide test section, as described in the preliminary report, and subjected to a total of 60 million tons of loading. The loading is accomplished by the oscillator, which sits on the test track directly over the test section. After completion of the oscillator test the ballast is removed from the test section and a representative sample obtained by quartering twice. This representative sample, which consists of about 20 cu ft of ballast, is then subjected to a complete screen analysis. It is then possible to compare the original gradation of the test ballast with its gradation after the oscillator test, and to determine the amount of degradation.

In addition to the above mentioned tests a number of tests are run on samples of the original ballast to determine various other properties. These tests include a specific gravity and absorption test, sodium sulfate soundness test, and Los Angeles abrasion test. These tests are all run in accordance with ASTM test methods.

Samples for the sodium sulfate soundness tests consist of three different sizes of aggregates as follows: 300 grams No. 4 to ⅜ in, 1000 grams ⅜ in to ¾ in, and 1500 grams ¾ to 1½ in. After five cycles of the soundness test the loss for each of the three sizes of aggregates is determined by re-screening over the sieve corresponding to the minimum size for each size range. A weighted average loss is then computed for the aggregate.

In addition to the usual determination of loss through the No. 12 sieve a complete sieve analysis is run on the Los Angeles abrasion samples after the test.

A group of tests are run on the fines (–No. 40) obtained from the screening of the ballast sample after completion of the oscillator test. These tests include the Atterberg limits, a permeability test of the falling-head type, and a cementing value test. The cementing value test is an unconfined compressive strength test run on specimens molded in a 1⅜-in by 1⅜-in by 2¾-in split mold. The water contents at which the samples are molded correspond to that required to produce a neat cement paste of normal consistency as required by the ASTM specification for running Tensile Strength of Hydraulic Cement Mortars. The paste is worked down in the mold with a spatula to eliminate air pockets. The molded samples are then moist cured for 1, 7, or 28 days and are subjected to an unconfined compression test at the completion of the curing period.

Test Results

The number of samples tested thus far is not sufficient to permit any pertinent conclusions to be drawn at this time.

Report on Assignment 11

Chemical Control of Vegetation

Collaborating with Signal Section and Communication Section, AAR

C. E. Webb (chairman, subcommittee), C. R. Bergman, M. W. Cox, L. J. Deno, H. S. Leard, J. R. Scofield, W. O. Trieschman, A. A. Winter, R. C. Young.

For the last two years your committee has presented as information results of investigations made by the research staff of the Engineering Division, AAR, in connection with this assignment. The following report is divided into two parts. Part 1 is a resumé of the research at Iowa State College, the University of Florida, and Montana State College, sponsored by the committee and directed by the personnel of the institutions as noted in the report. Part 2 is a resumé of some field investigations on various roads made by the research staff, AAR, under the general direction of G. M. Magee, director of engineering research. The field work for the research staff, supervised by Rockwell Smith, research engineer roadway, was performed largely by J. A. Fellman, test assistant roadway, who prepared the report on this work.

Both parts are presented as information.

Part 1

Fourth Annual Report on AAR Cooperative Weed Control Project[1]

W. E. Loomis, E. C. Rodgers, R. L. Warden, and R. E. Frans[2]

Expanded research in the 1954 season, plus continuing observations on repeat treatments and on the carry-over effects of former treatments, gives us the best basis so far available for estimating the effectiveness of various herbicides under railroad conditions. The general conclusion is that the control of roadbed and right-of-way vegetation is a maintenance problem which requires the continuous attention of trained personnel and generally more money than is now allocated to the project. We have found no indications that vegetation can be permanently eradicated, even by the most expensive treatments. Indeed, attempts to control all plant growth for a single season by one treatment may not be successful or economical.

On the other hand, those railroads that are using the better available treatments persistently, and with proper attention to timing and other factors, are obtaining satisfactory control at costs that should average about $50 per mile per year, and not exceed $100 under the more adverse conditions. The key to these results is uninterrupted atten-

[1] This is a report of a cooperative project, supported in part by the Association of American Railroads, between the Association, the Iowa and Montana Agricultural Experiment Stations, and the Department of Agronomy, University of Florida, with the cooperation of local railroads in the three areas.

[2] Respectively: Professor of Plant Physiology, Iowa Agriculture Experiment Station, Ames, Iowa; Professor of Agronomy, University of Florida, Gainesville, Fla.; Assistant Agronomist, Montana Agricultural Experiment Station, Bozeman, Mont.; and Research Associate, Iowa Agricultural Experiment Station.

tion and treatment. Postponement of weed control maintenance permits the build-up of weed seeds on the track and invasion by hard-to-eradicate perennials. This indicates that continuous control may be cheaper than intermittent, as well as more effective.

Multiple Problems

Roadbed vegetation may be classified in three groups: annual grasses and weeds; perennial grasses; and perennial broad-leaf plants, including brush and vines. (Minor species, as Equisetum, may be thrown with one or the other of the last two groups.) These are arranged in the approximate order of increasing difficulty of eradication, although the grass-broad leaf problem will vary with species and conditions. While some herbicides, as the newer oils, are active against all three groups, the different groups represent separate problems in many instances.

Annual weeds may be controlled by burning or by any of several quick-acting chemicals. Two difficulties are encountered: (1) Treatments are not repeated frequently enough, seed levels are maintained, and no progress is made toward reducing the infestation; or (2) one or a few species escape a particular treatment and develop so rapidly with decreased competition as to nullify much of the gain. Fireweed may escape chlorate sprays, and ragweed recovered on some plots sprayed with oils the past season.

Effective control, even of annuals, requires repeat treatments or the use of longer lasting and more expensive chemicals, such as the phenyl ureas. Even with these, late plants may produce seed and establish new infestations. Plots treated with CMU at Ames this year produced heavy seed crops of prostrate spurge, normally a minor weed, which may be expected to be abundant next year. The heavy aromatic oils which we recommended last year have continued to be effective, although, as noted above, some trouble was observed with recovery of ragweed on plots sprayed only once. A more serious problem was encountered, however, in the experience of one railroad that purchased spray oil assumed to be equivalent to our experimental heavy catalytic oil, number L–8764. The railroad considered the results more satisfactory than burning, but it was obvious from casual inspection of the area that the oil was too light, and the results inferior to those obtained with L–8764. We suspect that purchases purely on the basis of price will be incompatible with the obtaining of the best herbicidal oils, particularly until more exact specifications can be written for these materials.

Our observation that one oil, reported to contain 35 percent of aromatics, was better than a more expensive oil with 55 percent, has been confirmed. Experiments are underway to identify toxic fractions in oils more exactly. In general, aromatic compounds are more toxic than aliphatic, particularly in speed of action, although the higher boiling point fractions of the aliphatic oils show effective, slow-acting toxicity at rates of 100 gal an acre or more. It seems probable that some unidentified component in the higher boiling point, aromatic fraction may be responsible for the good results obtained with L–8764 and similar oils.

The results shown in Fig. 1 indicate the possibilities of oil sprays. This area was heavily infested with brome grass, slough grass and other plants. Spraying twice a year with 130 gal per mile (65 gal per acre) for two years has not only controlled annuals and top growth, but has eradicated the brome grass and promises to kill slough grass, one of the toughest plants in Iowa, within another year or two. On the basis of our continuing results under varying conditions, we feel that a rate of 160–180 gal per mile may be generally more satisfactory than the 120–130 gal used in our earlier experiments. If these oils can be purchased for 11 cents the chemical cost of two sprays per year will not exceed $40. As mentioned earlier, these oils are moderately dirty and greasy. At the present time such oils should be purchased only on the basis of *demonstrated* phyto-

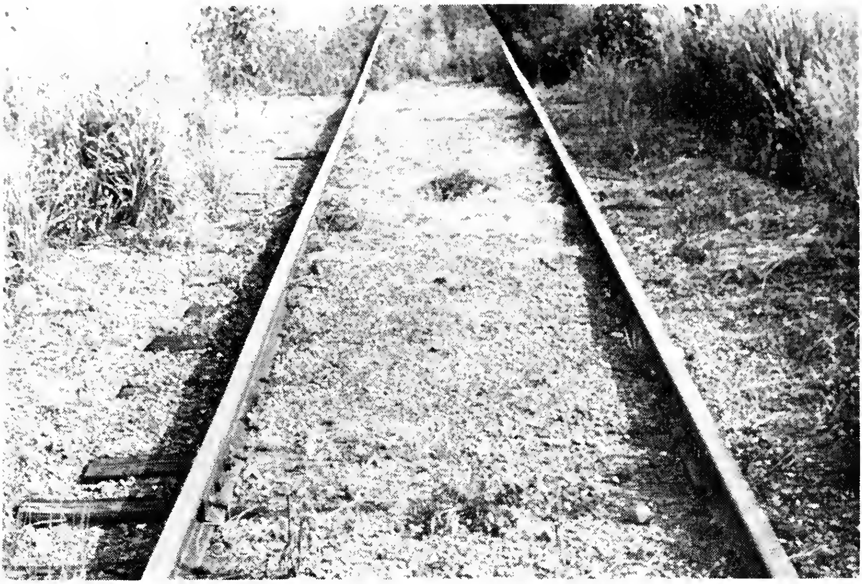


Fig. 1—This plot was sprayed 4 times in 2 years with a heavy aromatic oil at the rate of 60–70 gal/A. A continuation of the treatment promises to free the roadbed of the plants, mostly perennial grasses, originally present.

toxicity. The most effective oils in our tests have been from midcontinent crudes, *catalytic* recycle, with *endpoints* between 700 and 725 deg F. Other things being equal, a high aromatic content is desirable, but an oil with the same endpoint and 50 percent aromatics has been slightly less effective than a 35 percent oil. One suspects that a variation in the cracking process has influenced the proportions of some particularly active fraction in the two oils. Attempts to identify these materials will receive major attention during the coming year.

The development of an effective and commercially practical repellent would return sodium arsenite to the list of relatively inexpensive chemicals for use on annual weeds. Two materials tested the past year were completely repellent to sheep and effectively so to cattle under Iowa conditions. Sheep did not even graze near the areas sprayed with arsenic plus repellent. Cattle nibbled at the treated vegetation, then moved on to otherwise less desirable, untreated areas. Extensive tests will be necessary before general recommendations can be made, but good kill of annual weeds was obtained with as little as 80 lb of As_2O_3 per mile (40 lb per acre) when applied as sodium arsenite with an effective wetting agent. The wetting agent makes the arsenic a contact killer and reduces difficulties due to soil and climatic conditions.

Perennial Grasses

Grasses are possibly the most objectionable roadbed vegetation because of their dense, succulent growth and their tendency to build soil and hold moisture in the ballast. It should be recognized, however, that grasses are very effective competitors, and their removal may have the effect of releasing other species that were previously unnoticed.

Trichloroacetic acid (TCA), and its methylated analogue, Dalapon, are primarily grass killers. Sodium chlorate and the phenyl ureas, such as CMU, are also effective against grasses. We have used an application of 40 lb TCA and 80 lb chlorate to the acre as a standard treatment for perennial grasses on the roadbed. TCA, 30 lb, plus 120 lb of chlorate, gives equivalent results at about the same price. These combinations cost about $50 per mile, and must be repeated once or twice where vegetation is heavy and resistant. Also, these chemicals may be leached away by heavy rains and decompose fairly rapidly in the soil, so that an early application to control quack or Bermuda grass will not prevent late reinfestation by annual weeds and grasses. TCA–chlorate sprays started in January or March and repeated at 60-day intervals were the most effective treatments on Seaboard track at Gainesville, Fla., this year (Fig. 2), but a single application of TCA–chlorate, plus 10 lb of CMU, was cheaper and nearly as effective. In the last two years at Ames the effectiveness of some TCA–chlorate sprays has been reduced by rain. Treatments of 10 lb CMU and 80 lb chlorate made at the same time have resisted the leaching effects of the rain and have controlled late annual weeds without a second treatment or burning. The CMU mixture has cost about 50 percent more than the TCA. Half of this difference is recovered by avoiding a late summer follow-up treatment, and the remainder may be considered insurance against weather hazards under Iowa conditions. There still remains the difficulty that CMU is a wettable powder rather than a solution, but the suspensibility of the product is being improved, and if the price can be brought down again, CMU 10 lb–chlorate 80 lb per acre, or some similar mixture, could become a standard of comparison for spraying grassy track.

The value of adding chlorate to phenyl urea sprays has been questioned on the grounds that the ureas are general killers and that one-half pound of chlorate per square

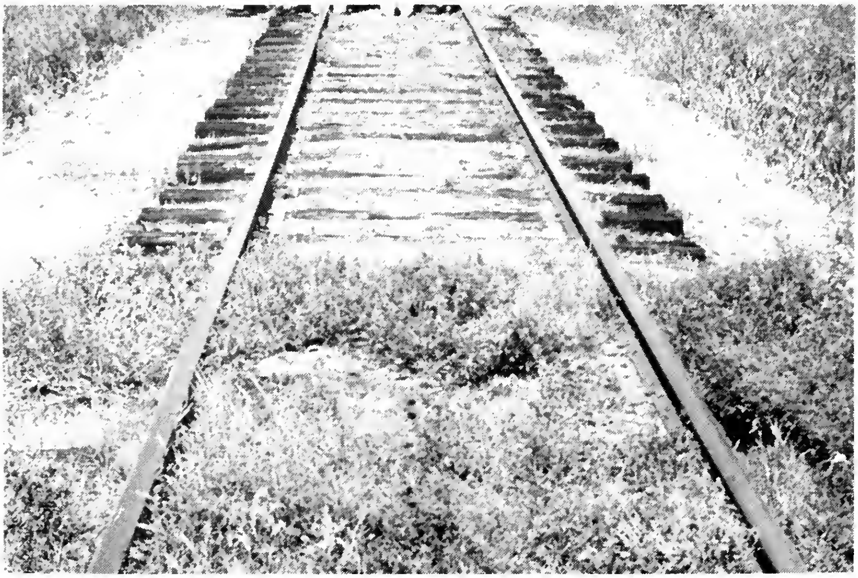


Fig. 2—Control of resistant roadbed vegetation in Florida with four applications of TCA, 40 lb-chlorate, 80 lb. It should be possible to keep this track clear with 2 treatments a year after the first year.

rod can have little effect. In spite of pot tests showing near universal toxicity for CMU, for example, some species escape treatments made in the field, and the small quantity of chlorate may help in controlling plants resistant to CMU and its dichloro analogue DMU. Since both of these compounds, particularly the second, are only slightly soluble, chlorate may penetrate and act upon the roots while the phenyl urea is held near the surface. This effect was shown this year in a test on a brome grass–alfalfa meadow. Ten pounds of CMU killed 97 percent of the brome and only 61 percent of the deep rooted alfalfa. With 80 lb of chlorate added, the figures were 99 and 95 percent. Results in a track test at Ames are shown in Table 1. The early treatment with TCA–chlorate was washed out. CMU, 10 lb–chlorate 80 lb, was equal to CMU 20 on an average, and better in controlling some types of regrowth.

TABLE 1—CMU IN HERBICIDAL COMPARISONS AT AMES, 1954

	Percentage Control on September 23		
Treatment	*Appl. May*	*Appl. July*	*Average*
TCA, 40–Chlor., 80	27	69	48
CMU 10	80	61	70
CMU 20	88	74	81
CMU 40	89	86	87
CMU, 10–Chlor., 80	78	85	81

At Gainesville Fla., CMU alone was poor in 1952, very good in March 1953, and poor again this year. Different areas have been used each year. This year CMU at 10 lb was added to 40–80 TCA–chlorate with some gain. CMU was not used with chlorate only. At Bradenton, Fla., 30 lb of DMU or 40 lb of the more soluble CMU controlled Bermuda, whereupon a vigorous growth of trumpet and red vine invaded the track from adjoining, unsprayed areas. In contrast, very few vines invaded the Bermuda grass checks (Fig. 3.)

Timing is vital in controlling grasses at reasonable cost. March, April and May have been the best months for spraying quack and brome grasses in Iowa, with June fair, and treatments after the middle of July generally ineffective. Last year, only the March treatments were fully satisfactory in Florida. This year, applications in January, March and June were compared. The order of effectiveness was generally March, January, June. In Montana, September applications, before freeze-up, have given exceptional results in a single trial. We suspect that this response reflects favorable moisture conditions for movement and action of the herbicides during the early spring. We showed in other research 20 years ago, however, that chlorate is effective in fall applications, provided it is not carried below the rooting zone of the plants by fall rains.

Broadleaf and Woody Plants

TCA–chlorate or CMU–chlorate are soil-acting, general sterilants. As such they will kill most broadleaf or woody plants, although their use for this purpose is not always economical. The phenoxyacetates, 2,4–D and 2,4,5–T, are specific for these plants, but their use is limited by the crop damage hazard. Late sprays, timed to avoid crop damage, are likely to be less effective. The use of oil-emulsion carriers and low volatile esters should aid in penetration and retention of these late, or very early, sprays and increase their effectiveness. 2,4–D is of little value as a foliage spray when mixed with fortified or aromatic oil, chlorate, arsenic, and other quick-acting chemicals which destroy the leaves before the 2,4–D can penetrate into the plant. Dormant sprays are only a partial

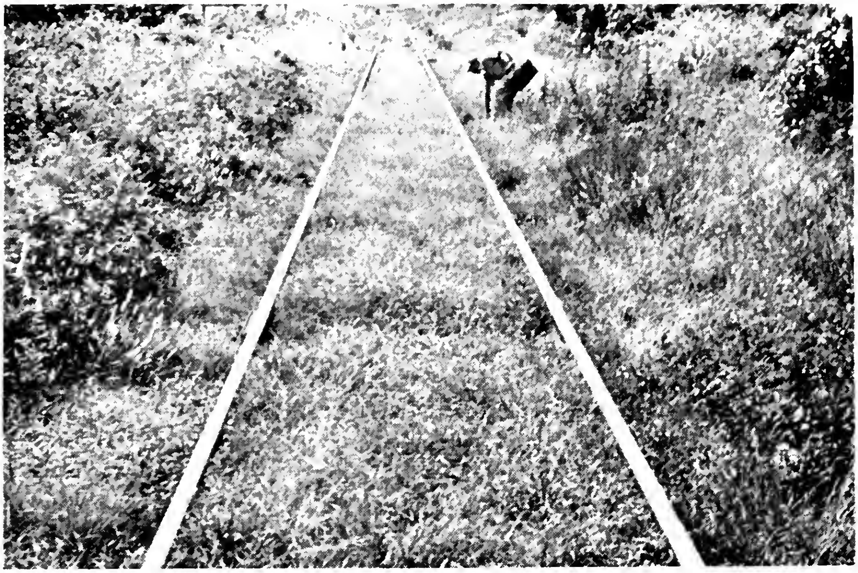


Fig. 3 (Upper)—Untreated track at Bradenton, Fla., 1954; mainly Bermuda grass. Lower—40 lb CMU in April eradicated the Bermuda, but vines are invading from the unsprayed sholders.

exception. Oils increase penetration through the bark of woody plants, but the less toxic fuel oils will generally give better results than oils high in aromatics. A heavier oil than is normally used would have theoretical advantages for either late summer, oil emulsion sprays, or dormant sprays where these are used.

Where trumpet, dewberry and other vines are prevalent, a brush killer program will be required to kill them. Fig. 3 shows that this spray must be applied to the shoulder and fill, preferably before clearing grasses, etc., from the roadbed. A swinging boom with a light canvas drag to keep down drift should be useful.

Summary

TCA–chlorate continues to give satisfactory results on grass and mixed vegetation when rainfall conditions are favorable. Two to four treatments per year may be required for heavy, resistant vegetation. CMU–chlorate has advantages in duration of control and resistance to leaching that may offset its higher cost and greater difficulty of handling.

Medium heavy, catalytic cycle oils continue to be most promising for lighter jobs and less resistant vegetation. We hope to have the assistance of oil companies and railroad people this year in writing better specifications for such oils.

Repellents to be used with sodium arsenite sprays may increase the use of this chemical at relatively low rates as a contact herbicide. More research is needed on late-season, oil emulsion sprays with brush killers.

Weed control like that shown in Fig. 1 can be obtained for about $50 per mile per year under present conditions. The control shown in Fig. 2 will cost $200 per mile the first year and should drop to $50 to $100 thereafter.

Part 2

Chemical Control of Vegetation—1954 AAR Report

Summary

The salient features of any investigation into the results obtained by chemical weed control along railroad right-of-ways in the United States and Canada are the great variation in climatic conditions and vegetative populations throughout the country. Because of these, for the purpose of this investigation, the United States has been tentatively divided into seven large general regions. These groupings ar based mostly on climate and vegetation. Observations of weed or brush control were made on 21 railroads scattered throughout the first 6 of these regions. The map, Fig. 1, shows the outlines of these regions.

Observations this year have further substantiated the belief that there is no one chemical panacea for controlling vegetation. Each chemical can be considered as a tool to be used in getting a job done. Consideration should be given to all factors involved in choosing the right chemical tools for the type of job required. For example, an area infested with perennial grasses requires a different type of treatment than an area covered with annual weeds or deep rooted perennial weeds.

Another necessary factor is proper application. The proper chemicals may be used, but careless application may produce poor results. The most common error is to reduce the rate of application. If a planned treatment is at the optimum rate, a 20 percent reduction in chemical used may reduce effectiveness by 50 percent or more. If enough chemical is not available to treat a whole line properly it would be better to skip areas

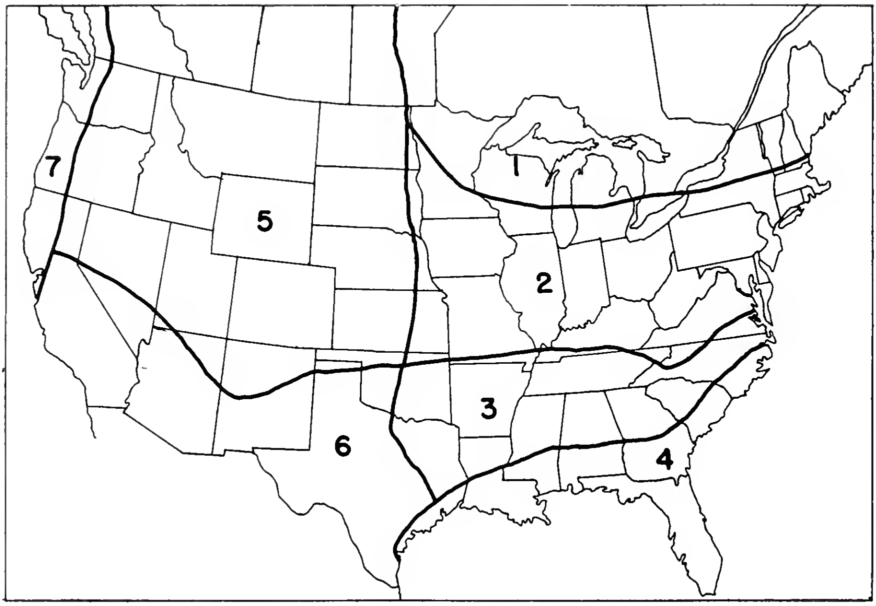


Fig. 1.

of least growth and concentrate on the most troublesome sections. While poor application can upset a properly planned program, good application cannot make up for poor planning. Good over-all results have been observed where one man has been responsible for the planning and proper execution of the entire program. This points up the need for properly trained, conscientious men all along the line, who understand the job they are trying to do. This applies to railroads doing their own spraying and to custom applicators.

The chemicals most widely used in railroad weed control this year were sodium chlorate and aromatic oils.

Observations have again confirmed previous indications that chlorate applied in the spring just after growth has begun gives the best root kill. A good treatment, 160 lb per acre, may last all season in the north, but in the south one or two repeat treatments may be necessary. Oftentimes only a contact killer, such as oil, is needed as a follow-up treatment. Under certain favorable conditions mid-season applications work well, but most of the time too much of the chemical is used in killing the rank top growth to give the desired root kill.

TCA–chlorate mixtures have been used extensively, and under the right conditions are good grass killers. Many times, results with mid-season applications of TCA have been very poor and unpredictable. During hot dry weather it would seem advisable to replace the TCA with chlorate.

Herbicidal oils, usually obtained from a distillation process, with an aromatic content of 50 percent or more, were used very extensively this year with varying results. Where one treatment of oil was expected to replace a soil-sterilant type chemical, results were disappointing. But where oils were recognized as contact killers to be repeated as needed, results were satisfactory. In a number of cases some oils were reported to have effected a partial root kill, especially when the weather was dry. Deep rooted perennials seem to give the most trouble in oil treatments. Just what properties of an oil are responsible for its herbicidal activity is not known, and much work is being done on this subject. High boiling points, aromatic content, sulphur content, and source are some of the things that are being checked.

A new grass killing chemical, Dalapon, (a,a–dichloropropionic acid) was used commercially on railroads this year with promising results. Dalapon is translocated through the leaves of grass down to the roots, so the vegetation should be actively growing at time of application. When mixed with 2,4–D it has given good all-around control. It appears to be very effective on Bermuda grass at rates of 40 lb or more per acre.

Formulas containing small amounts of arsenic were used this year as contact killers with good results.

This past summer many sections of the country suffered drought conditions and this usually prolonged the length of control of chemical weed treatments. Some treatments that worked well in these areas this year may be less effective in normal years, especially with light treatments.

Roadbed Treatments

Following is a summary of treatments observed listed according to regions.

Region 1

Sodium chlorate, used at the rate of at least 135 lb per acre and applied in late April or May, has produced good results when applied for two or more years. This type of treatment applied for four years has practically eliminated grass from the treated area—mostly quack grass and bluegrass. Sometimes native annual weeds appear in August, but usually they are not too troublesome. An oil treatment should clean these up nicely. There are a number of species which are resistant to this treatment, namely: horsetail (joint grass, scouring rush) milkweed, bindweed, smartweed (tanweed) and wild rose. When a small amount of MCP (2-menthyl-4-chlorophynoxyacetic acid) is added to the sodium chlorate it appears to increase the effectiveness of the treatment on some broad-leaved weeds.

TCA–chlorate at the rate of 35 lb TCA and 70 lb chlorate per acre was applied in mid June. Growth at this time was quite rank and some of the grasses had headed out. The treatment was not too effective and regrowth was fairly rapid. Considerable rain fell on some of the area and this may have affected the results adversely.

Region 2

Sodium chlorate with MCP applied at the rate of approximately 160 lb per acre (1.5 lb MCP) in yards in June gave good one season control, even with normal amount of rainfall, although toward the end of the season some annuals were seeding in.

A branch line treated with chlorate at 120 lb per acre in mid June gave very good one season control. Shortly after treatment a drought set in and lasted most of the summer.

A number of areas were treated with a mixture of arsenic, TCA and oil in June or July. It was applied at approximately 57 lb arsenic, 15 lb TCA, and 50 gal oil per acre. The treatment gave a rapid contact kill, and where rainfall was normal it lasted 3–4 weeks. In areas of drought results were good for 8 weeks or more.

Considerable quantities of various types of oils were used this season in this region.

One type used quite extensively was a very heavy oil with an endpoint around 750 deg F, pour point of 65 deg F, and 65 percent aromatics (also used in Regions 3, 4 & 6). This oil was very difficult to work with when temperature was under 65 deg, and good coverage of dense vegetation was hard to achieve. Where branch lines had been treated in June with 70 gal per acre results were spotty. Where sufficient coverage was obtained, good control was achieved for 6 weeks. This oil coats the ties and ground with a film that appears to retard regrowth. Where coverage was poor because of equipment or characteristics of the oil, results were poor.

This same oil when applied in yards during warm weather, at 100 gal per acre or more, gave good control for 2 months on weeds and grass. Milkweed, bindweed, and horsenettle were the first to come back.

A lighter oil, end point 675 deg, pour point minus 10 deg F, 50 percent aromatics, was used with excellent top kill and good control for a month. Coverage even in dense vegetation was good for a rate of 70 gal per acre. Where applied heavier it seemed to penetrate down among the roots of grass sod with excellent control. In some areas the addition of small amounts of 2,4–D gave better control of perennial broadleaved weeds.

Two other oils, one with an endpoint of 760 deg and 70 percent aromatics, the other with an endpoint of 635 deg F and 50 percent aromatics, mixed with water and applied 2 or 3 times as needed, controlled but did not eliminate vegetation for the season (also used in Region 3).

Region 3

A mixture of Dalapon and 2,4–D, at the rate of approximately 44 lb Dalapon and 2 lb 2,4–D per acre, was applied in June on a yard. Vegetation was growing actively and coverage was good. Season-long control was very good. In October the only species that had made any appreciable regrowth was nut grass, and it had been controlled for about 6 weeks. Horsenettle and clumps of broom sedge had made some regrowth. Johnson grass and Bermuda grass made a little regrowth only where the original infestation was very thick. The 2,4–D had apparently killed the broadleaved weeds. Two tracks that had not been treated were overrun with rank growth of weeds and grasses. The summer was quite dry, which quite probably also reduced the regrowth.

On one line a comparison was made between two formulas of TCA–chlorate. One contained ⅔ lb TCA to 2 lb chlorate per gal. The other, 1 lb TCA to 2 lb chlorate per gal. They were applied at the rate of approximately 40 gal per acre in June. Each treatment was effective for about 6 weeks. Shortly after treatment the heavier rate of TCA appeared to be more effective on Bermuda grass, but after 6 weeks there was no apparent difference in the treatments and regrowth was considerable.

A very heavy oil, with endpoint of 750 deg F and 65 percent aromatics (also used in Regions 2,4 & 6) was applied once in May at the rate of 70 gal per acre. The weather was warm and coverage was fairly good. Annual weeds and grasses were killed when completely covered by the oil. The top growth of nut grass, Bermuda grass and Johnson grass was killed, but after 6 weeks considerable regrowth was made from the roots. Trumpet vine and briars were defoliated by the spray. Many of these plants were rooted outside of the spray area and reinfestation started within a very short time.

On another line a different aromatic oil was used (endpoint over 720 deg F, 70 percent aromatics). It was mixed with water to try to increase coverage. Applications were repeated up to three times as needed. Vegetation, including considerable amounts of Johnson grass, horsenettle and briars, was controlled for the season (also used in Region 2).

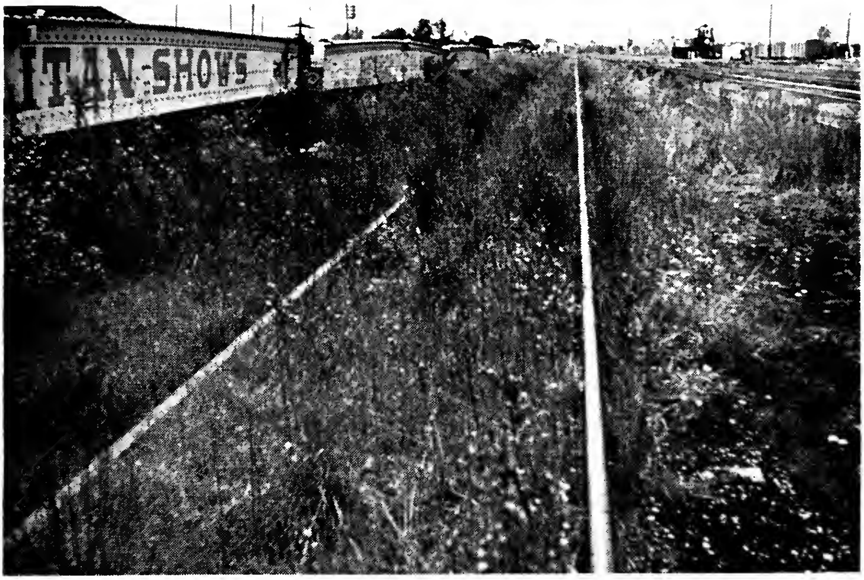


Fig. 2—Not treated. Photo taken in October 1954. Compare with Fig. 3.

Fig. 3—Treated in June 1954 with 44 lb of Dalapon and 2 lb of 2, 4–D per acre. Photo taken in October 1954.

Region 4

Dalapon, 44 lb and 2,4–D, 2 lb per acre, was applied on a branch line in June. In areas with susceptible crops nearby POP was substituted for 2,4–D. The results were generally good, but not as striking as those in Region 3. POP burns the tops of the grass before the Dalapon can be translocated to the roots.

One application of the same heavy oil (endpoint over 750 deg, 65 percent aromatics) as used in Region 3 was made with the same results (also used in Regions 2, 3 & 6).

Application of 40 lb TCA and 80 lb chlorate per acre was made in October in Florida. This treatment gave good control for the entire winter season.

Region 5

Chlorate applied once a year for 4 years in May at the rate of 135 lb per acre has almost cleared branch lines of vegetation. Spots of horsetail and smartweed (tanweed) have been resistant to the treatment. Some annual plants may appear in late summer but usually not enough to be troublesome. Much of the area had been covered with perennial grass sod, but most of that has been forced out of the treated region.

Light burning repeated at 3 to 4-week intervals has reduced vegetation on branch lines that were almost taken over by it.

CMU applied in May 1953 at the rate of 20 lb per acre on a branch line gave very good two-season control of quackgrass, bluegrass and bromegrass. During the second year growth of annual weeds and resistant broadleaved weeds, such as wild licorice, milkweed, wild rose and bindweed, was very rank and covered much of the area.

Region 6

A heavy oil (endpoint over 750 deg F, 65 percent aromatics) was applied once in May at the rate of 70 gal per acre (also used in Regions 2, 3 & 4). Control was good for about 6 weeks, and although the summer was very dry there was considerable regrowth. It seems that much of the oil was used to kill cheat grass (called wild oat) and wheat which were dying off naturally. Much of the regrowth was puncture vine.

An aromatic oil, with endpoint of around 650 deg F and about 50 percent aromatics, was sprayed twice at the rate of 100–115 gal per acre. The first treatment was in June and the second in August. The weather was very dry. The combination of two treatments and dry weather did a fairly good job of controlling the vegetation. Coverage was very good and both the early and late annuals were killed. Shallow-rooted perennials and grass made very little regrowth, but deep-rooted perennials, such as bindweed, reinfested the area appreciably.

A branch line that was quite heavily infested with weeds and grasses was treated late in April with approximately 65 lb chlorate and 15 lb TCA per acre. This was followed by an oil (endpoint above 740 deg F, 70 percent aromatics) treatment in July at 70 gal per acre. It was warm and moist at the time of application, and a drought set in a short time later. Even though the TCA–chlorate treatment was light, conditions were so favorable that top kill was good; also the root kill was good on grasses that were not too thick. The oil treatment killed the annuals that had seeded in and again knocked down the perennials. The dry weather helped to hold down regrowth so that in October the line looked very good, except where there had been heavy stands of Bermuda grass. Horsenettle, bluestem grass, yucca and nutgrass also made some regrowth, but they were not as prevalent as Bermuda grass. A close inspection revealed that cheat grass and wheat seeds were germinating in considerable quantities and will probably cover much of the area in late fall and early spring.

Right-of-Way Brush Control

Observations were made in late summer covering many areas in Canada where brush had been sprayed in 1952 or 1953. There were a number of variations in the type of chemicals used. The one that appeared to give the best results under average conditions was 2 lb 2,4–D and 2 lb 2,4,5–T per gal, usually mixed at the rate of 1 gal chemical to 100 gal water. The amine formulations appeared to give as good results as the esters in this area. Also, there was no difference in results with low volatile and regular esters.

On areas treated in 1952 with 50–50 mixture (2 lb 2,4–D and 2 lb 2,4,5–T in 100 gal water), where main species were poplar, elm, birch, willow, alder, cherry and hazel, regrowth was slight. Many of the dead stems had fallen down and the remainder were rapidly rotting. In many places it appeared that no brush had been present, but closer inspection revealed that the dead stems had fallen down and were not visible to the casual observer. There was some small regrowth from seedlings, but these were receiving much competition from weeds and grases that were covering the area. The kill where only 2,4–D was used was good (about 70 percent compared with over 90 percent for the mixture), but briars and raspberries were not affected much.

On similar areas treated in 1953 with the same 50–50 mixture there was practically no regrowth. Most of the stems were still standing, but they were rotting rapidly. There were some seedlings coming up, but grass was growing on much of the area formerly shaded by the foliage.

On sections sprayed in 1953 with the 50–50 mixture where other species, such as oak, maple and ash, were present, the kill was not as pronounced. Oak and ash that were in a position to receive good coverage showed very little regrowth, although they were still alive; those toward the outer edge of the sprayed area had some regrowth. Red maple was showing some regrowth throughout the right-of-way. These trees had regrown to about 50 percent of their original size.

In Kentucky, brush was sprayed in 1953 with a 50–50 mixture of 2,4–D and 2,4,5–T, 100 gal water to 1 gal chemical. Species present were sumac, sassafras, elm, cotton-

Fig. 4—Brush treated in 1953 with 2 lb of 2,4–D and 2 lb of 2,4,5–T per gal, mixed with 100 gal of water. Note that most of smaller brush on right has fallen down.

wood, sycamore and oak. The kill was very good on everything but the sassafras and oak. The oak was surviving, but regrowth was slight. Top kill was almost complete on the sassafras, but sprouts from the roots had grown up to 6 ft. On some ditch banks where the brush had been killed and the area burned in the fall, giant ragweed (horseweed) grew profusely this year. In many places it reached a height of 10–12 ft. On areas like this, treatments before seed time, with 1 or 2 lb per acre of 2,4–D would eliminate this tall growth and promote the growth of grasses and low growing weeds. These would, in turn, hold back reinvasion by brush.

In Southern Indiana, brush was treated in August 1954 with a 50–50 mixture of 2,4–D and 2,4,5–T, 100 gal water to 1 gal chemical. Observation at time of spraying indicated coverage was very good. Inspection in the fall showed almost complete defoliation, even on oak, ash, maple and sweetgum. An interesting feature of this job was that in many places the sides of the berm were covered with trumpet vine and briars, which were encroaching upon the track. These species were completely defoliated, with no regrowth by fall, except directly next to the rail where the only coverage was from drift.

Report of Committee 5—Track

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R. H. Timmins
Troy West
J. B. Wilson
M. J. Zeeman

Committee

(E) Member Emeritus.
* Died July 4, 1954.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

1. Revision of Manual.

   See reports on Assignments 2 and 3.

2. Track tools, collaborating with Committees 1 and 22 and with Purchases and Stores Division, AAR.

   Offers, for inclusion in Manual, rail tongs for use with crane, Plan No. 31–54 .... page 735

   Progress report on track spike lifter, claw bar, track chisel, track gage and tee socket wrench .... page 735

3. Plans for switches, frogs, crossings, spring and slip switches, collaborating with Signal Section, AAR.

   Offers recommendation affecting Portfolio of Trackwork Plans .... page 737

   Appendix 3–a—Service test of manganese steel casting in crossings at McCook, Ill.

   Progress report, submitted as information .... page 747

   Appendix 3–b—Service test of solid and manganese steel insert crossing, supported by steel T-beams and longitudinal timbers.

   Progress report, submitted as information .... page 749

   Appendix 3–c—Specifications for spring washers for use in special trackwork.

   Final report, submitted as information .... page 752

4. Prevention of damage resulting from brine drippings on track and structures, collaborating with Committee 15 and Mechanical Division, AAR.

5. Design of tie plates, collaborating with Committees 3 and 4.

6. Hold-down fastenings for tie plates, including pads under plates; their effect on tie wear, collaborating with Committee 3.

7. Effect of lubrication in preventing frozen rail joints and retarding corrosion of rail and fastenings.

8. Field measurement of forces resulting from rail anchorage. Advance report,* submitted and published in Bulletin 517, September–October 1954, page 283.

This assignment to be discontinued.

9. Critical review of the subject of speed on curves as effected by present-day equipment, collaborating with AAR Joint Committee on Relation Between Track and Equipment.

10. Methods of heat treatment, including flame hardening, of bolted rail frogs and split switches, together with methods of repair by welding.

11. Means of conserving labor and materials, including the adaptation of substitute noncritical materials, and specifications for the reclamation of released materials, tools and equipment, collaborating with Committee 3–A, General Reclamation, Purchases and Stores Division, AAR.

No report.

THE COMMITTEE ON TRACK,
L. L. ADAMS, *Chairman*.

AREA Bulletin 521, February 1955.

MEMOIR

Raymond Edgar Miller

Raymond Edgar Miller, chief engineer of the Frog and Switch Department of the Bethlehem Steel Company, Steelton, Pa., died on July 4, 1954. He was born in Wiconisco, Pa., on January 30, 1890. After attending public schools of Wiconisco, he was educated at Bucknell University, Lewisburg, Pa.

Mr. Miller joined the AREA in 1936 and was appointed as an Associate Member of Committee 5—Track, in 1938. He has served on Subcommittee 3, Plans for switches, frogs, crossings, etc., including track construction in paved streets, from 1938 to the time of his death.

Mr. Miller was a registered Professional Engineer in Pennsylvania. He was also much interested and active in the affairs of BPOE, of which he was a Life Member.

He was a faithful and valued member of the Evangelical and Reformed Church of Colonial Park, where he resided. Mr. Miller is survived by his wife Jane, a daughter Mrs. A. O. Birnie, a son Ralph H., three grandchildren, and one great grandchild.

During the years Mr. Miller worked with us on the Track committee, we learned to look to him for constructive criticism, sound common sense, whole-hearted cooperation, and friendly support. His many friends on the Track committee sincerely regret his untimely passing and will miss him as a friend and fellow worker. The AREA has lost a valued member.

Report on Assignment 2

Track Tools

Collaborating with Committees 1 and 22, and with the Purchases and Stores Division, AAR

C. E. Peterson (chairman, subcommittee), L. L. Adams, H. S. Ashley, R. J. Bruce, T. F. Burris, E. W. Caruthers, W. E. Cornell, L. E. Donovan, K. E. Dunn, D. C. Hastings, C. N. King, W. N. Myers, M. P. Oviatt, J. M. Rankin, R. C. Slocomb, Troy West, J. B. Wilson.

Your committee submits the following recommendation with respect to the Manual, for adoption:

Pages 5–6–9 to 5–6–25, incl.

PLANS FOR TRACK TOOLS

Plan 31–54—Rail Tongs for Use With Crane

This type of rail tong is in use on practically all railroads today. Therefore, it was decided to include it in the AREA track tools plans to take the place of the former AREA Rail Tongs for Use With Crane, which was eliminated from the AREA track tool plans several years ago. Also, list new plan in index to plans on page 5–6–9. The new plan is presented on page 736.

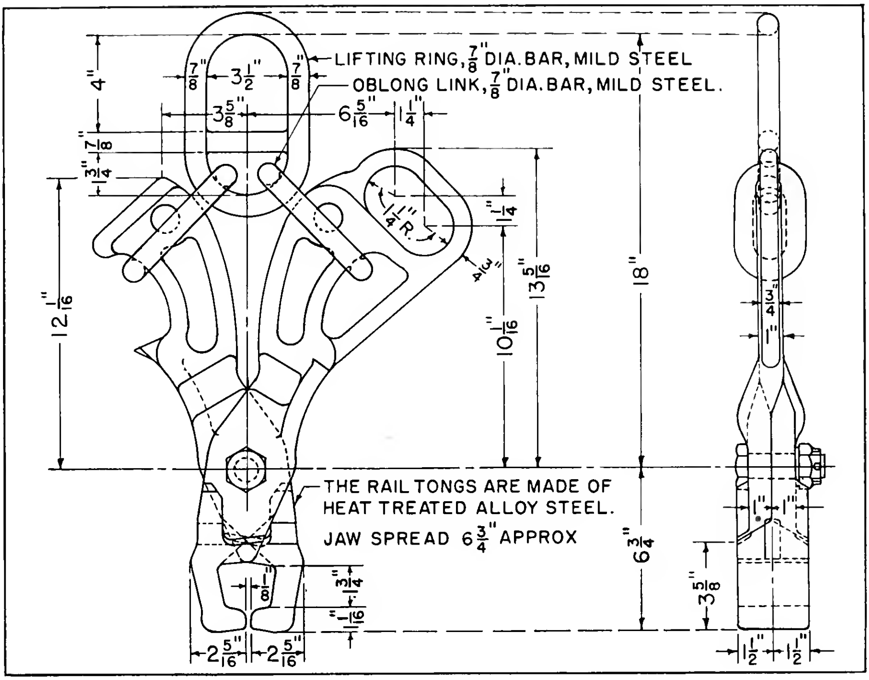
The following is a progress report, submitted as information. It is a continuation of the progress report found in Vol. 55, 1954, page 701.

Track Spike Lifter

The new track spike lifter has been in test for one year on five different railroads and found to be satisfactory.

Track Spike Lifter, Plan 32–54, has been prepared and will be recommended as a new AREA track tool in the near future.

The tool is used to advantage to raise spikes in the turnout area, particularly at the guard rail plates, switch plates, rail brace plates, frog plates, and in any location where the standard claw bar cannot easily reach the spike head. It is also valuable as a tool for use after derailments in the removal of spikes which have been damaged



Plan 31–55—AREA rail tongs for use with crane.

as a result of being struck by wheels or equipment, and for use on rail renewal jobs to remove spikes that cannot be raised with a spike puller.

The tool is designed to do a job safely and to avoid the danger of injury resulting from misuse, such as striking the heel of a claw bar or striking a track chisel held in an awkward position.

Claw Bar

The jaw end of the present claw bar is not satisfactory due to excessive hardness. An investigation has been made, which included laboratory hardness tests, and it was concluded that further study should be made as it seems that it may be possible to improve the design.

The following changes in the jaw end have been suggested and will be followed up with actual field tests:

1. To grind out the upper lip of the slotted portion for its entire length to a radius that will fit the under side of the cut track spike.
2. Also grind the 7-in radius 1 in back from the tip so as to make the section at the tip thinner in order to secure more flexibility.

Track Chisel

The present AREA Track Chisel Plan 17–53 does not specify the hardness required for this tool. It was recommended that a check be made of the hardness required and have it inserted on the plan.

A study is being made of the chemical analysis for all carbon steel track tools, and when it is completed the committee will make a recommendation.

Suggested Track Gage

The present AREA track gage cannot be used for gaging at guarded frogs; therefore, there is a need for an additional track gage to take care of this situation.

A study is being made of a suggested track gage which will be similar in design to the present AREA wood center track gage, with the exception that the guard check gage will be located on the top of the gage.

Tee Socket Wrench

This type wrench, for removing drive spikes from switch plates and road crossing planks, has been recommended as a new track tool. It is in use on the railroads today.

Various sizes of sockets are used on this tool, depending on the type of head of the drive spike. Drive spikes are manufactured with various types of heads, some being square and others rectangular. It is suggested that the subject of various sizes of drive spike heads be investigated with the manufacturers in order to standardize on one type of head so that only one socket size will be required.

Report on Assignment 3

Plans for Switches, Frogs, Crossings, Spring and Slip Switches

Collaborating with Signal Section AAR

M. J. Zeeman (chairman, subcommittee), L. L. Adams, D. B. Barge, Jr., T. H. Beebe, W. R. Bjorklund, R. J. Bruce, H. F. Busch, E. W. Caruthers, H. B. Christianson, E. D. Cowlin, H. W. Cox, Jr., F. W. Creedle, P. H. Croft, L. E. Donovan, J. W. Fulmer, V. C. Hanna, M. J. Hassen, A. E. Haywood, A. B. Hillman, A. F. Huber, C. H. Johnson, C. N. King, T. R. Klingel, W. N. Myers, H. B. Orr, M. P. Oviatt, C. E. Peterson, S. H. Poore, J. A. Reed, M. K. Ruppert, R. D. Simpson, R. C. Slocomb, T. R. Snodgrass, R. H. Timmins, Troy West, J. B. Wilson.

Your committee has undertaken a comprehensive review of all the plans and specifications in the Portfolio of Trackwork Plans. This study, which has been underway for the past several years, has developed that several worthwhile improvements in design should be included in the plans and specifications and that certain designs which are not in general use should be omitted. It has also been found desirable to consolidate details applicable to many plans on one plan for clearer presentation and ease of revision if revision is found necessary in the future.

Many of the revisions developed in this study apply to several plans. Hence, to avoid repetition in the description of the revisions proposed for individual plans, the revisions applying to groups of plans are outlined below:

Revision I, Location and Size of Spike Holes.

A paragraph No. 40 on page 1 of Appendix A is recommended to describe this detail, and contrary information is deleted or corrected on Plans Nos. 113–55, 117–55, 223–55, 224–55, 401–55, 405–55, 407–55, 408–55, 504–55, 700F–55 and 835–55.

Revision II, Point and Flangeway Dimensions for Manganese Frogs and Crossings.

A comprehensive Plan No. 600B–55 to cover this information for all angles of frogs and crossings is presented, and these details are referred to on Plans Nos. 600–55, 621–55, 641–55, 671–55, 750–55, 751–55, 768–55, 769–55, 771–55, 772–55, 773–55, 774–55, 775–55, 782–55 and 783–55.

Revision III, Depression of Frog Points.

The depression of all manganese frog and crossing points for angles below 25° where wing wheel risers are not used, and of all spring frog points, is recommended. This revision is incorporated on Plans Nos. 401–55, 405–55, 407–55, 408–55, 490–55, 600–55, 600B–55, 611–55, 612–55, 613–55, 614–55, 615–55, 621–55, 622–55, 623–55, 624–55, 625–55, 641–55, 671–55, 750–55, 751–55, 761–55, 768–55, 769–55, 774–55 and 775–55.

Revision IV, Tie Layouts and Plates for Crossings.

(a) *For Crossing Angles 60° to 90°.* Timber supports are recommended for the heavier traffic run and continuous base plates for the other run with integral external extensions and filler plates between the rails on the timbers. These plates are 1″ thick for rails over 110 lb per yd and ¾″ thick for lighter sections.

(b) *For Crossing Angles Below 60°.* Diagonal ties are recommended with corner base plates ¾″ thick for all rail sections.

(c) For crossings of all angles flat tie plates 8″ wide, with shoulders, are recommended for all ties not otherwise protected within the limits of the crossing and for at least one tie beyond each external joint and for all ties beyond which are skewed more than 10° from normal position. These plates are ¾″ thick under the rail, unless 1″ thickness is required to properly support the rails on the same tie.

(d) *Welded "U" stops are recommended for crossing base plates.* This revision is incorporated on Plans Nos. 700F–55, 700G–55, 700H–55, 701–55, 702–55, 703–55, 704–55, 705–55, 706–55, 708–55, 710–55, 719–55, 755–55, 757–55, 761–55, 768–55, 769–55, 771–55, 772–55, 773–55, 774–55, 775–55, 782–55, and 783–55.

(e) Individual crossing plans do not illustrate the plates and refer to the applicable tie layout and plate plan for the details of plates to be furnished unless purchaser supplies a layout plan showing other tie and plate arrangements.

Revision V, Solid Manganese Frog and Crossing Sections.

Heavier sections and reinforcement along base edges in critical areas is recommended for solid manganese frogs and crossings. This revision is incorporated on Plans Nos. 671–55, 771–55, 772–55, 773–55, 774–55, 775–55, 782–55 and 783–55.

Revision VI, Depth Hardening of Manganese Castings.

A paragraph, No. 410, is recommended for Appendix A to describe this feature when specified for the impact areas of manganese structures, and these areas are defined on solid manganese crossing Plans Nos. 771–55, 772–55 and 773–55.

Revision VII, Reference to Spring Switch Construction.

A note is recommended for certain switch plans reading as follows: "Details for Spring Switches—See Plan Basic No. 181 for revisions in switch points, rods, plates and bills of material recommended for spring switch operation." This revision is incorporated on Plans Nos. 111–55, 112–55, 115–55, 116–55, 117–55, 118–55, 123–55, 124–55, 125–55, 126–55, 127–55 and 128–55.

Revision VIII, Elimination of Girder Rail Construction.

The withdrawal of all plans showing girder rail construction is recommended because this design of rail is not generally being rolled at present, as "Tee" rail construction is suitable for modern vehicular traffic. Girder rail details are deleted from Plans Nos. 982–55, 987–55, 988–55 and 989–55, and withdrawal of Plans Nos. 776–40, 777–40, 780–40, 781–40, 983–54, 984–35, 985–35, 986–35, 1002–52 and 1003–52 is recommended.

Revision IX, Shoulder Bolts.

The use of shoulder bolts instead of thimbles is recommended for the hinged joints of switches and spring frogs as the patent on this construction has expired and it is being used by many railroads. This revision is incorporated on the following Plans: Nos. 111–55 to 128–55, incl., 190–55, 221–55, 401–55, 405–55, 813–55, 814–55 and 836–55.

Revision X, Bonding.

Details for bonding now called for on several plans are deleted and a note added to all plans where bonding is required, reading as follows: "Bonding. Per current AAR Signal Section recommended practice." This revision is incorporated on Plans Nos. 320–55, 322–55, 323–55, 324–55, 401–55, 405–55, 407–55, 408–55, 600–55, 611–55, 612–55, 613–55, 614–55, 615–55, 621–55, 622–55, 623–55, 624–55, 625–55, 641–55, 671–55, 691–55, 708–55, 710–55, 761–55, 768–55, 769–55, 774–55 and 775–55.

Revision XI, Flare Details.

Plan Basic No. 350 shows the angle, width of opening, and bevel at the end of all Tee rail flares in frogs and crossings, and these details are deleted from the individual plans. This revision is incorporated on Plans Nos. 320–55, 322–55, 323–55, 324–55, 401–55, 405–55, 407–55, 408–55, 600–55, 611–55, 612–55, 613–55, 614–55, 615–55, 621–55, 622–55, 623–55, 624–55, 625–55, 701–55, 702–55, 703–55, 704–55, 705–55, 706–55, 708–55, 710–55, 755–55, 757–55, 761–55, 768–55, 769–55, 771–55, 772–55 and 773–55.

Plans Recommended for Adoption

Revisions applying to individual plans are described for each plan. Editorial corrections to improve the presentation or to clear up inconsistencies are included in the new issues. Copies of the revised plans are presented in a supplement to Bulletin 521—Part 2, except for those marked with an asterisk. The revisions in the plans marked with an asterisk are of such a nature that they can be understood readily from the description stated, so it is believed that the expense of presenting prints of them with this report can be avoided.

Accordingly, your committee presents for adoption as recommended practice the following plans and specifications in the AREA Portfolio of Trackwork Plans and Specifications and the withdrawal of the previous issue of the plan where noted in the description.

**Plan No. 111–55, 16′–6″ Straight Split Switch with Uniform Risers.*

Revision of Plan No. 111–51, same title, to incorporate revisions VII and IX.

**Plan No. 112–55, 16′–6″ Straight Split Switch with Graduated Risers.*

Revision of Plan No. 112–51, same title, to incorporate revisions VII and IX.

**Plan No. 113–55, 11 –0″ Straight Split Switch with Uniform Risers.*

Revision of Plan No. 113–51, same title, to incorporate revisions I and IX.

**Plan No. 114–55, 11′–0″ Straight Split Switch with Graduated Risers.*

Revision of Plan No. 114–51, same title, to incorporate revision IX.

**Plan No. 115–55, 22′–0″ Straight Split Switch with Uniform Risers.*

Revision of Plan No. 115–51 same title, to incorporate revisions VII and IX.

**Plan No. 116–55, 22′–0″ Straight Split Switch with Graduated Risers.*
Revision of Plan No. 116–51, same title, to incorporate revisions VII and IX.

**Plan No. 117–55, 30′–0″ Straight Split Switch with Uniform Risers.*
Revision of Plan No. 117–51, same title, to incorporate revisions I, VII and IX.

**Plan No. 118–55, 30′–0″ Straight Split Switch with Graduated Risers.*
Revision of Plan No. 118–51, same title, to incorporate revisions VII and IX.

**Plan No. 121–55, 13′–0″ Curved Split Switch with Uniform Risers.*
Revision of Plan No. 121–51, same title, to incorporate revision IX.

**Plan No. 122–55, 13′–0″ Curved Split Switch with Graduated Risers.*
Revision of Plan No. 122–51, same title, to incorporate revision IX.

**Plan No. 123–55, 19 –6″ Curved Split Switch with Uniform Risers.*
Revision of Plan No. 123–51, same title, to incorporate revisions VII and IX.

**Plan No. 124–55, 19′–6″ Curved Split Switch with Graduated Risers.*
Revision of Plan No. 124–51, same title, to incorporate revisions VII and IX

**Plan No. 125–55, 26′–0″ Curved Split Switch with Uniform Risers.*
Revision of Plan No. 125–51, same title, to incorporate revisions VII and IX.

**Plan No. 126–55, 26′–0″ Curved Split Switch with Graduated Risers.*
Revision of Plan No. 126–51, same title, to incorporate revisions VII and IX.

**Plan No. 127–55, 39′–0″ Curved Split Switch with Uniform Risers.*
Revision of Plan No. 127–51, same title, to incorporate revisions VII and IX.

**Plan No. 128–55, 39′–0″ Curved Split Switch with Graduated Risers.*
Revision of Plan No. 128–51, same title, to incorporate revisions VII and IX.

**Plan No. 190–55, Diagram Illustrating Preferred Names of Parts for Split Switches.*
Revision of Plan No. 190–52, same title, to incorporate revision IX.

Plan No. 221–55, Details for Switch Points.
Revision of Plan No. 221–51, same title, to incorporate revision IX.

Plan No. 223–55, Switch Plates and Rigid Rail Braces.

Revision of Plan No. 223–47, same title, to incorporate revision I and to change rail seats in shoulder plates from "Rail Base + 1/16 in" to "Rail Brace + 3/32 in" and to delete rigid brace and plate details for rails lighter than 90 lb. Square instead of bevelled corners are shown for the vertical ends of the butt insulated gage plate, details 3103 and 4103.

**Plan No. 224–55, Switch Plates and Adjustable Rail Braces.*
Revision of Plan No. 224–40, same title, to incorporate revision I and to change rail seats in shoulder plates from "Rail Brace + ⅛ in" to "Rail Brace + 3/32 in"

**Plan No. 251–55, Switch Stands and Appurtenances.*
Revision of Plan No. 251–41, same title, to incorporate reference to Signal Section Plan No. 1444A–Electric Switch Lamps.

**Plan No. 320–55, Data and Sections for Bolted Rigid Frogs.*
Revision of Plan No. 320–41, same title, to incorporate revisions X and XI.

**Plan No. 322–55, No. 4, No. 5 and No. 6 Bolted Rigid Frogs.*
Revision of Plan No. 322–51, same title, to incorporate revisions X and XI.

**Plan No. 323–55, No. 7, No. 8 and No. 9 Bolted Rigid Frogs.*
Revision of Plan No. 323–51, same title, to incorporate revisions X and XI.

**Plan No. 324–55, No. 10, No. 11 and No. 12 Bolted Rigid Frogs.*
Revision of Plan No. 324–51, same title, to incorporate revisions X and XI.

Plan No. 350–55, Toe Rail Flares for Frog and Crossing Flangeways.
New plan to incorporate revision XI.

Plan No. 401–55, No. 10 Spring Rail Frog.

Revision of Plan No. 401–51, same title, to incorporate revisions I, III, IX, X and XI.

Plan No. 405–55, No. 10 Spring Rail Frog, Short Spring Rail Type.

Revision of Plan No. 405–51, same title, to incorporate revisions I, III, IX, X and XI.

**Plan No. 407–55, No. 9, No. 11 and No. 12 Spring Rail Frogs.*

Revision of Plan No. 407–51, same title, to incorporate revisions I, III, X and XI.

**Plan No. 408–55, No. 9, No. 11 and No. 12 Spring Rail Frogs—Short Spring Rail Type.*

Revision of Plan No. 408–51, same title, to incorporate revisions I, III, X and XI.

**Plan No. 490–55, Diagram Illustrating Preferred Names of Parts for Spring Rail Frogs.*

Revision of Plan No. 490–52, same title, to incorporate revisions III and IX.

**Plan No. 504–55, Guard Rails—Tee Rail Designs with Planed Flares and Flat Plates.*

Revision of Plan No. 504–40, same title, to incorporate revision I and to change the caption "Shoulder Tie Plate" to read "Guard Rail Tie Plate."

**Plan No. 590–55, Preferred Names of Parts for Guard Rails.*

Revision of Plan No. 590–40, same title, to illustrate a separator block in the center of the guard rail.

Plan No. 600–55, Data and Sections for Rail Bound Manganese Steel Frogs.

Revision of Plan No. 600–51, same title, to incorporate revisions II, III, X and XI. Base of heel rails are not machined on gage side to clear base of guard rails at flares.

Plan No. 600B–55, Point and Flangeway Dimensions for Manganese Frogs and Crossings.

General revision of Plan No. 600B–34, Standard Manganese Steel Frog Point and Flangeway Layout, per revision II and III to incorporate on one plan all the details required for frogs and crossings.

**Plan No. 611–55, No. 4 and No. 5 Rail Bound Manganese Steel Frogs.*

Revision of Plan No. 611–51, same title, to incorporate revisions III, X and XI.

**Plan No. 612–55, No. 6, No. 7 and No. 8 Rail Bound Manganese Steel Frogs.*

Revisions of Plan No. 612–51, same title, to incorporate revisions III, X and XI.

**Plan No. 613–55, No. 9, No. 10 and No. 11 Rail Bound Manganese Steel Frogs.*

Revision of Plan No. 613–51, same title, to incorporate revisions III, X and XI.

**Plan No. 614–55, No. 12, No. 14 and No. 15 Rail Bound Manganese Steel Frogs.*

Revision of Plan No. 614–51, same title, to incorporate revisions III, X and XI.

**Plan No. 615–55, No. 16, No. 18 and No. 20 Rail Bound Manganese Steel Frogs.*

Revision of Plan No. 615–51, same title, to incorporate revisions III, X and XI.

**Plan No. 621–55, Data and Sections for Rail Bound Manganese Steel Frogs for Rails 112 Lb. and Heavier.*

Revision of Plan No. 621–47, same title, to incorporate revisions II, III, X and XI.

**Plan No. 622–55, No. 6, No. 7 and No. 8 Rail Bound Manganese Steel Frogs for Rails 112 Lb. and Heavier.*

Revision of Plan No. 622–51, same title, to incorporate revisions III, X and XI.

**Plan No. 623–55, No. 9, No. 10 and No. 11 Rail Bound Manganese Steel Frogs for Rails 112 Lb. and Heavier.*

Revision of Plan No. 623–51, same title, to incorporate revisions III, X and XI.

**Plan No. 624–55, No. 12, No. 14 and No. 15 Rail Bound Manganese Steel Frogs for Rails 112 Lb. and Heavier.*

Revision of Plan No. 624–51, same title, to incorporate revisions III, X and XI.

**Plan No. 625–55, No. 16, No. 18 and No. 20 Rail Bound Manganese Steel Frogs for Rails 112 Lb. and Heavier.*

Revision of Plan No. 625–51, same title, to incorporate revisions III, X and XI.

Plan No. 641–55, Solid Manganese Steel Self Guarded Frogs.

Revision of Plan No. 641–51, same title, to incorporate revisions II, III and X. The design of the adjustable toe block is changed. Rail Sections lighter than 90 lb per yd are omitted.

Plan No. 671–55, Solid Manganese Steel Frogs.

Revision of Plan No. 670–51, same title, to incorporate revisions II, III, V and X Design II frogs with easer extension at toe ends and rail sections lighter than 90 lb are deleted.

**Plan No. 691–55, Diagram illustrating Preferred Names of Parts for Solid Manganese Steel Frogs.*

Revision of Plan No. 691–42, same title, to omit the plan of Design II Toe Easer Extension Frog.

**Plan No. 700–55, Crossing Designs and Recommended Practices.*

Revision of Plan No. 700–50 to incorporate revision IV. Change Paragraph 6—"Plates" to read: "6. PLATES. It is recommended that base and tie plates be provided for all ties within the limits of the crossing and at least one tie beyond each external joint, and on all ties within and adjacent to the crossing that are skewed more than 10° from their vertical position with the track. The preferred arrangement of plates are shown on Plans Basic No. 700F, 700G, 700H and 700J. However, the size of the base plates and the number and lengths of the tie plates varies with the angles." Paragraph 7–C–2: Delete "minimum" in second line. Change Paragraph 7–C–3—"Tie Layout" to read: "Tie Layout and Plates. Complete information for the location of ties and/or timbers and details of plating should be shown when other arrangements are wanted than those presented on the AREA plan referred to."

Plan No. 700F–55, Tie Layouts and Plates for Crossing Angles 90° to 60° incl.

Revision of Plan No. 700D–42, Crossing Plates, to incorporate revision IV for angles stated.

Plan No. 700G–55, Tie Layouts and Plates for Crossings, Angles Below 60° to 35° incl.

Revision of Plan No. 700D–42, Crossing Plates, to incorporate revision IV for angles stated.

Plan No. 700H–55, Tie Layouts and Plates for Crossings, Angles below 35° to above 14° 15′.

Revision of Plan No. 700D–42, Crossing Plates, to incorporate revision IV for angles stated.

Plan No. 700J–55, Tie Layouts and Plates for Crossings, Angles 14° 15′ to 8° 10′ 16″ incl.

Revision of Plan No. 700D–42 Crossing Plates, to incorporate revision IV for angles stated.

Plan No. 701–55, Bolted Rail Crossings, Angles 90° to 50° incl., Three Rail Design.

Revision of Plan No. 701–48, same title, to incorporate revisions IV and XI.

Plan No. 702–55, Bolted Rail Crossings, Angles 90° to 50° incl., Two Rail Design.

Revision of Plan No. 702–48, same title, to incorporate revisions IV and XI.

Plan No. 703–55, Bolted Rail Crossings, Angles Below 50° to 35° incl., Three Rail Design.

Revision of Plan No. 703–48, same title, to incorporate revisions IV and XI.

Plan No. 704–55, Bolted Rail Crossings, Angles below 50° to 35° incl., Two Rail Design.

Revision of Plan No. 704–48, same title, to incorporate revisions IV and XI.

Plan No. 705–55, Bolted Rail Crossings, Angles below 35° to 25°, incl., Three Rail Design.

Revision of Plan No. 705–48, same title, to incorporate revisions IV and XI. Long point rails are extended ahead of ½″ points. Steel strut braces are to be 1¼″ thick.

Plan No. 706–55, Bolted Rail Crossings, Angles Below 35° to 25°, incl. Two Rail Design.

Revision of Plan No. 706–48, same title, to incorporate revisions IV and XI. Long point rails are extended ahead of ½″ points. Steel strut braces and reinforcing straps for bent crossing rails are to be 1¼″ thick.

Plan No. 708–55, Bolted Rail Crossings, Angles Below 25° and Above 14° 15′.

Revision of Plan No. 708–41, same title, to incorporate revisions IV, X and XI and a note calling for a minimum bolt spacing of 5″.

Plan No. 710–55, Bolted Rail Crossings Angles 14° to 15″ to 8° 10′ 16″, incl.

Revision of Plan No. 710–50, Bolted Rail Crossings Angles 14° 15′ to 8° 10′ inclusive, to incorporate revisions IV, X and XI and a note calling for minimum bolt spacing of 5″.

**Plan No. 719–55, Tie Layouts for Railroad Crossings.*

Revision of Plan No. 719–42, Tie Layout for Railroad Crossing, to incorporate revision IV.

Plan No. 750–55, Designs and Dimensions of Manganese Steel Inserts for Crossings of Angles Below 45° to Above 14° 15′ for Rails 6″ and more in Height.

Revision of Plan No. 750–47—Designs and Dimensions of Manganese Steel Inserts for Crossings of Angles from 14° 15′ to 45° 00′ for Rails 6″ and more in Height, to incorporate revision II. The length of the manganese running surface of the internal portion of center frog castings is increased for angles below 20°.

Plan No. 751–55, Design and Dimensions of Manganese Steel Inserts for Crossings of Angles Below 45 to Above 14° 15′ for Rails less than 6″ in Height.

Revision of Plan No. 751–47, Designs and Dimensions of Manganese Steel Inserts or Crossings of Angles from 14° 15′ to 45° 00′ for Rails less than 6″ in Height, to incorporate revision II. Square ends are shown for the ends of the running rails abutting manganese castings and the lengths of the castings have been increased for angles below 20° to correspond to those shown on Plan No. 750–55.

Plan No. 755–55, Manganese Steel Insert Crossings, Angles Below 45° to 35°, incl.

Revision of Plan No. 755–47, same title, to incorporate revisions IV and XI. Running Rails abutting manganese castings are shown with square ends. Steel reinforcing straps for bent crossing running rails are to be 1¼″ thick.

Plan No. 757–55, Manganese Steel Insert Crossings, Angles Below 35° to 25°, incl.

Revision of Plan No. 757–47, same title, to incorporate revisions IV and XI. Running Rails abutting manganese castings are shown with square ends. Steel reinforcing straps for bent running rails are to be 1¼″ thick.

Plan No. 761–55, Manganese Steel Insert Crossings, Angles Below 25° and Above 14° 15′.

Revision of Plan No. 761–47, same title, to incorporate revisions II, IV, X and XI. Running Rails abutting manganese castings are shown with square ends.

Plan No. 768–55, Manganese Steel Insert Crossings, Angles 14° 15′ to 8° 10′ 16″, incl. for Rails less than 6″ in Height.

Revision of Plan No. 768–51, Manganese Steel Insert Crossings, Angles 14° 15′ to 8° 10′, inclusive, for Rails less than 6″ in Height, to include revisions II, III, IV, X and XI. Running Rails abutting manganese castings are shown with square ends.

**Plan No. 769–55, Manganese Steel Insert Crossings, Angles 14° 15′ to 8° 10′ 16″, incl., for Rails 6″ and more in Height.*

Revision of Plan No. 769–50, Manganese Steel Insert Crossings, Angles 14° 15′ to 8° 10′, inclusive, for Rails 6″ and more in Height, to incorporate revisions II, III, IV, X and XI.

Plan No. 771–55, Solid Manganese Steel Crossings, Angles 90° to 60°, incl.

Revision of Plan No. 771–40, same title, to incorporate revisions II, IV, V, VI and XI. External running rails are to be furnished with holes spaced 3½" x 6" for attachment to casting. Top projection of internal joint bars is omitted.

Plan No. 772–55, Solid Manganese Steel Crossings, Angles below 60° to 40°, incl.

Revision of Plan No. 772–40, same title, to incorporate revisions II, IV, V, VI and XI. External running Rails are to be furnished with holes spaced 3½" x 6" for attachment to casting. Top projection of internal joint bars is omitted.

Plan No. 773–55, Solid Manganese Steel Crossings, Angles below 40° to 25° incl.

Revision of Plan No. 773–40, same title, to incorporate revisions II, IV, V, VI and XI. Rolled rail guards are shown for all flares of end corners. External running rails are to be furnished with holes spaced 3½" x 6" for attachment to casting. Top projection of internal joint bars is omitted.

Plan No. 774–55, Crossings with Solid Manganese Steel Frogs and Interior Rolled Closure Rails, Angles Below 25° and Above 14° 15', Single Rail Construction.

Revision of Plan No. 774–41, Crossings with Solid Manganese Steel Frogs and Interior Rolled Closure Rails, Angles Below 25° 00' and Above 14° 15', Single Rail Construction, to incorporate revisions II, III, IV, V and X.

Plan No. 775–55, Crossings with Solid Manganese Steel Frogs and Interior Rolled Closure Rails, Angles 14° 15' to 8° 10 16" Inclusive.

Revision of Plan No. 775–50, Crossings with Solid Manganese Steel Frogs and Interior Rolled Closure Rails, Angles 14° 15' to 8° 10' inclusive, Single Rail Construction, to include revisions II, III, IV, V and X. End Frogs are shown with toe filler extensions, Design 1, and references to end frogs with toe easer extension, Design 2, are deleted. (See report for Plan No. 671–55 above.)

Plan No. 782–55, Articulated Manganese Steel Crossings, Angles 90° to 60°, incl.

Revision of Plan No. 782–48, same title, to incorporate revisions II, IV and VI Hole spacings in external rail arms are changed from 2½" x 6½" to 3½" x 6".

Plan No. 783–55, Articulated Manganese Steel Crossings, Angles Below 60° to 40°, incl.

Revision of Plan No. 783–48, same title, to incorporate revision II, IV and VI. Hole spacings for external rail arms are changed from 2½" x 6½" to 3½" x 6".

Plan No. 790–55, Data for Gages and Flangeways Showing Limits Where Gage Is not Widened for Curvature.

Revision of Plan No. 790–34, same title, to show the "Check Gage for Frog and Crossing Flangeways" and delete the "Frog and Crossing Limit Gage."

Plan No. 813–55, No. 8 Double Slip Switch.

Revision of Plan No. 813–42, same title, to incorporate revision IX. Switch point planing Detail 5100 is specified for the curved inside switch points and planing Detail 6100 for the straight outside switch points. Sixteen single joint bars are called for in bill of material.

Plan No. 814–55, No. 10 Double Slip Switch.

Revision of Plan No. 814–42, same title, to incorporate revision IX. Switch point planing Detail 5100 is specified for the curved inside switch points and planing Detail 6100 for the straight outside switch points. Twenty single joint bars are called for in the bill of material.

**Plan No. 821–55, Movable Point Crossings.*

Revision of Plan No. 821–42, same title, to incorporate revision IX.

**Plan No. 835–55, Plates for No. 10 Double Slip Switch.*

Revision of Plan No. 835–42, same title, to incorporate revision I. Seats in plates are shown "Rail Base + $\frac{3}{32}$ in" for plates with single rail seats and at adjustable braces, and "Rail Base + ⅛ in" or "Knuckle Rail Base + ⅛ in" for plates with two or more seats.

**Plan No. 836–55, Fittings for Double Slip Switches and Movable Point Crossings.*

Revision of Plan No. 836–42, same title, to incorporate revision IX.

Plan No. 982–55, 200′ Radius Tongue Switch and Mate Solid Manganese Steel for Use in Paved Streets.

Revision of Plan No. 982–54, 200′ Radius Tongue Switch and Mate Solid Manganese Steel for use in Paved Streets for 7″ and 9″ Girder Rails and Tee Rail Connections, to incorporate revision VIII.

Plan No. 987–55, Straight Double Tongue Switches for Engine Wheel Base not more than 12′ 6″ with Two Pair of Flanged Wheels, Solid Manganese Steel for Use in Paved Streets.

Revision of Plan No. 987–54, Straight Double Tongue Switches for Engine Wheel Base not over 12′ 6″ with Two Pairs of Flanged Wheels, Solid Manganese Steel for Use in Paved Streets, 7″ and 9″ Girder Rails and Tee Rail Connections, to incorporate revision VIII.

Plan No. 988–55,Straight Double Tongue Switches for Engine Wheel Base not over 13′ 0″ with Three Pairs of Flanged Wheels, Solid Manganese Steel, for Use in Paved Streets.

New plan to accommodate conditions stated in title with other details similar to Plans No. 987–55 and 989–55.

Plan No. 989–55, Straight Double Tongue Switches for Engine Wheel Base over 13′ 0″ but not Exceeding 19′ 0″, Solid Manganese Steel, for Use in Paved Streets.

Revision of Plan No. 989–54, Straight Double Tongue Switches for Engine Wheel Base over 13′ 0″ but not exceeding 19′ 0″, Solid Manganese Steel, for use in Paved Streets, 7″ and 9″ Girder Rails and Tee Rail Connections, to incorporate revision VIII.

**Plan No. 1001–55, Data for Tee Rail Sections.*

Revision of Plan No. 1001–52, same title, to show 140 RE in the Association types and to delete 140 PS in the railroad special types.

**Plan No. 1010–55, Permissible Variations in Completed Frogs.*

Revision of Plan No. 1010–42, same title, to show at the "Section of a Spring Rail Frog", the clearance at top of hold down horn as (⅛″ maximum, $\frac{1}{16}$″ minimum) and at the bottom of the horn as (¼″ maximum, $\frac{1}{16}$″ minimum). In description under "Alinement", the following is deleted: "For manganese frogs because of the increased thickness of point (See Plan Basic No. 600B) this line shall not lie more than $\frac{1}{16}$″ within the point."

Specifications for Special Trackwork, Appendix A–55

Revisions of Appendix A–52 are recommended to incorporate the following items: Add on Page 1 per Revision I:

40. Spike Holes

Unless otherwise specified on Plans, spike holes shall be punched ¾″ square except those holes at rail base edges shall be ¾″ wide by $\frac{13}{16}$″ long nominally $\frac{1}{16}$″ (⅛″ max. 0 min.) under edge of rail base or into rail seat at plate shoulder. The edge of holes shall not be less than 1¼″ from ends or sides of plates except for hook twin tie plates, or where necessary to match spike holes in fittings or to clear structural members.

Delete, on Pages 2 and 3 per Revision VIII, Article 2. Open Hearth Steel Girder Rails of the Plain, Grooved and Guard Types, Paragraphs 201, 202, 203 and 204.

Delete, on Page 3, Article 3. Rolled Manganese Steel Rail, Paragraph 301. This material is not available at any American rail mill.

Add on Page 4 per Revision VI:

410. Depth Hardening

When specified, the impact areas described on the Trackwork Plans shall be hardened by hammering or pressing integrally cast pads of suitable thickness and area to a minimum surface Brinell hardness of 350 for the areas within 1″ of the gage or guard lines and a minimum Brinell hardness of 320 for the balance of the hardened area. The method to be used is at the option of the manufacturer and shall insure that the depth from the tread surface to the normal hardness of cast manganese steel shall not be less than 1″ near the flangeway walls, tapering to not less than ½″ throughout the hardened area.

Unless otherwise specified, one hardness reading only shall be required on each hardened area. This reading shall be taken at the intersection of lines 1″ from, and parallel to, the gage or guard lines.

In case any hardness measurement does not meet the specified requirements, two additional measurements shall be made, one on either side of the original impression, about 1″ distant and parallel with the gage or guard line. If both of these measurements meet the requirements, the original reading shall be discarded, and these two readings be reported in its place.

Castings failing to meet the hardness requirement will be acceptable provided the cost for the hardening process is deducted from the price.

Plan to Be Withdrawn Per Revision IV

Plan No. 700–D–42, Crossing Plates.

Plans to Be Withdrawn and not Otherwise Mentioned in This Report per Revision VIII

Plan No. 776–40, Solid Manganese Steel Crossings, Steam Railroad over Electric Railway, Angles 90° to 60°, incl.

Plan No. 777–40, Solid Manganese Steel Crossings, Steam Railroad over Electric Railway, Angles Below 60° to 40°, incl.

Plan No. 780–40, Solid Manganese Steel Crossings for 7″ and 9″ Girder Rails, Angles 90° to 60°, incl., for Steam Railroad over Electric Railway and for Steam Railroad Tracks both ways.

Plan No. 781–40, Solid Manganese Steel Crossings for 7″ and 9″ Girder Rails, Angles Below 60° to 40°, incl., for Steam Railroad over Electric Railway and for Steam Railroad Tracks both ways.

Plan No. 983–54, Solid Manganese Steel Frogs for 7″ and 9″ Girder Rails.

Plan No. 984–35, Nos. 4 and 5 Frogs, Iron Bound Manganese Steel Center, for 7″ and 9″ Girder Rails.

Plan No. 985–35, Nos. 6 and 8 Frogs, Iron Bound Manganese Steel Center, for 7″ and 9″ Girder Rails.

Plan No. 986–35, No. 10 Frogs, Iron Bound Manganese Steel Center, for 7″ and 9″ Girder Rails.

Plan No. 1002–52, Girder Rail Sections.

Plan No. 1003–52, Data Sheet for ATEA Girder Grooved Rails, Girder Guard Rails and Plain Girder Rails.

Errata

The items listed in the Proceedings, Vol. 55, 1954, pages 703 to 706, outlining minor inconsistencies and errors in the Portfolio of Trackwork plans are incorporated in the revisions proposed in this report.

The collaboration of the Standardization Committee of the Manganese Track Society in the drafting of the plans and in the review of the specifications in this report is gratefully acknowledged.

Reports by the Research Staff, AAR

Your committee presents as information the following reports prepared by the research staff of the Engineering Division, AAR:

Appendix 3 (a)—Service Tests of Designs of Manganese Steel Castings in Crossings at McCook, Ill. Progress Report.

Appendix 3 (b)—Service Tests of Solid and Manganese Steel Insert Crossings Supported by Steel T-Beams and Longitudinal Timbers. Progress Report.

Appendix 3 (c)—Specifications for Spring Washers for Use in Special Trackwork. Final Report, consisting of Part 1—Crossing Frog Bolt Tension Tests, and Part 2—Specifications and revisions suggested for later consideration as recommended practice and publication in the Manual (Portfolio of Plans.)"

These subjects were reported last year in Appendices 3 (a), 3 (b), and 3 (c), respectively, and published in the Proceedings, Vol. 55, 1954, pages 706 to 712, incl.

Appendix 3–a

Service Tests of Designs of Manganese Steel Castings in Crossings at McCook, Ill.

This is a progress report of the service performance of the test castings in the crossings between the double-track lines of the Baltimore & Ohio Chicago Terminal Railroad and the Atchison, Topeka & Santa Fe Railway at McCook, Ill., and is submitted as information.

Foreword

Last year's report on the condition of the test castings was published in the Proceedings, Vol. 55, 1954, page 706. The test now includes four AAR test castings and another casting provided by the B&OCT. Two of the castings are of solid pedestal design manufactured by the Johnstown Works of the United States Steel Corporation, and two frogs are of the deepened flangeway design provided by the Ramapo Ajax Division of the American Brake Shoe Company. The fifth casting is of the previously tested Morden–Ramopo design with the flangeways shot peened prior to placing it in service. Plans and photographic views of the solid pedestal and deepened flangeway castings have been published in the Proceedings, Vol. 55, 1954, pages 13–16. The test castings are in the same location as shown on page 11 of the next above reference. The last inspection was made on August 17, 1954, at which time the shot-peened casting had been in service 5.3 years and all other test castings, 1.8 years. Subsequent to last year's report the Santa Fe has revised its signal system to permit reversed movements on its main tracks. The Santa Fe stated that about 10 percent of the traffic operates in the reverse direction. An occasional westward train on the B&OCT operates through the crossover at the interlocking tower and traverses the crossings on its eastward track. The results of the last inspection are included in the following paragraphs.

USS Solid Pedestal Castings

There are two of these frogs in service, and the only difference between them is that one was depth hardened and the other was not. The depth-hardened casting had a total length of flangeway fillet cracks of 8⅛ in, divided as follows: 5¼ in, Santa Fe receiving corner; 1¼ in, B&OCT leaving corner and 1⅝ in, B&OCT receiving—Santa Fe leaving corner. There were no cracks at the guard rail junctions, and no welding of the tread corners has been done.

The other solid pedestal casting, without depth hardening, is in the corner diagonally opposite to the depth-hardened frog. The unhardened casting had 2½ in of flangeway cracks and a short crack at each guard rail junction. The flangeway cracks were divided equally between the B&OCT leaving—Santa Fe receiving and B&OCT receiving corners. The inspection of April 8, 1954, showed that the B&OCT receiving corner was smashed down and a piece of tread had broken out. This frog was repaired by welding and grinding on April 28, 1954. On August 17, 1954, it was observed that the weld metal on the Santa Fe receiving—B&OCT leaving corner had mashed down in the flangeway and was separating from the parent metal. Grinding the material out of the flangeway was suggested to the B&OCT. Welding of that corner may be required in a few months. It is believed that the difference in the flangeway cracks of 8⅛ in. in the depth-hardened casting and 2½ in. in the unhardened casting was accidental, and the depth hardening was not the cause of the excess cracking.

Ramapo Deepened Flangeway Casting

These two castings are in the crossing carrying westward traffic on both tracks. The AAR casting is in the NE corner of the crossing and the other one, provided by the B&OCT, is in the SW corner. The AAR casting had no flangeway fillet cracks or cracks at the guard rail junctions. However, there was a crack, 2¼ in. in length, near the longitudinal center line of the flangeway of the Santa Fe external arm. The west end of the crack was 3¼ in east of the apex of the B&OCT receiving—Santa Fe leaving corner. The crack was located along the sloping part of the flangeway floor, and as stated last year, may have been the result of shrinkage when the casting was poured. The flangeways of this frog, including the deepest portion, were ground to a smooth finish.

The other deepened flangeway frog, which was furnished by the B&OCT, had a total of 6¾ in of flangeway cracks. One crack, 5 in long at the B&OCT receiving corner, had ½ in. in the B&OCT flangeway and 4½ in. in the Santa Fe, and only about 1 in was in the fillet. The 4½-in crack extended west from the fillet at the corner to the center line of the Santa Fe flangeway floor. There was another crack, 1¾ in long, parallel with and close to the center line of the flangeway floor in the Santa Fe external arm. The latter crack overlapped by 1 in the west end of the 5-in crack. There were no flangeway cracks at the guard rail junctions. The deep portion of the flangeways in this frog had not been ground and the surfaces were rough. It is possible that these stress raisers may have influenced the formation of the cracks.

Shot-Peened Casting, Morden–Ramapo Design

This casting was placed in service April 25, 1949. In October 1952 it was removed from the test corner in the crossing carrying eastward traffic on both tracks to the NE corner of the other crossing in the eastward track of the B&OCT. After 5.3 years of service this casting had developed 33 in of cracks in the flangeways and 1¾ in of cracks in the running surface at the Santa Fe running rail junction. Eleven months prior to this inspection the flangeway cracks had an aggregate length of 30 in. The tread corners were in reasonably good condition and the welded metal showed no evidence of failing. Judging from the recent performance of this casting, it should be serviceable for several more months.

Acknowledgement

The Association is indebted to the B&OCT for its invaluable aid in the conduct of the field tests for more than a decade.

Appendix 3–b

Service Tests of Solid and Manganese Steel Insert Crossings Supported by Steel T-Beams and Longitudinal Timbers

This is a progress report, submitted as information.

These service test installations of crossings to determine performance with respect to two types of support were last reported in the Proceedings, Vol. 55, 1954, page 708.

Installations of 1946

This test includes two crossings, each of the solid manganese and insert types in the double-track lines of the Indiana Harbor Belt Railroad and the Chicago and Western Indiana Railroad (operated by the Belt Railway Company of Chicago) near 55th St. and Cicero Ave., Chicago. One crossing of each type has the original design of an integrally welded structural steel T-beam support, and the second one of each type has framed timbers. The two crossings with the steel substructure were maintained on the original asphaltic ballast until April 1952. Subsequently, these crossings have been supported on ¾-in stone ballast.

Fig. 1 is included to show the location of the crossings and extent of the flangeway cracks observed on August 12, 1954. During the last year of service, the total length of the cracks of the solid manganese crossing increased from 84 in to 99 in. in the steel-supported castings. The corresponding figures for the solid crossing on timber were 64 in to 77 in. The insert crossing on the steel support had one crack 4 in long, as compared with 3¾ in a year ago. Three corners in this crossing have developed no cracks. The insert crossing on timber had a total of 12½ in of cracks in 3 corners, compared with 11¼ in a year ago. The line of the crossings was reasonably good, but the steel supported crossings were low and needed raising. Two of the clip bolts were broken on crossing A (Fig. 1). Several of the clip bolts were loose in the external arms of the two crossings and a few were loose in the internal arms. No welding was needed for the four crossings, but some grinding on the solid crossings was needed. Although the solid crossings have numerous cracks, it is judged that they will be serviceable for a few more years. The insert crossings are in good condition and should be serviceable longer than the solid crossings.

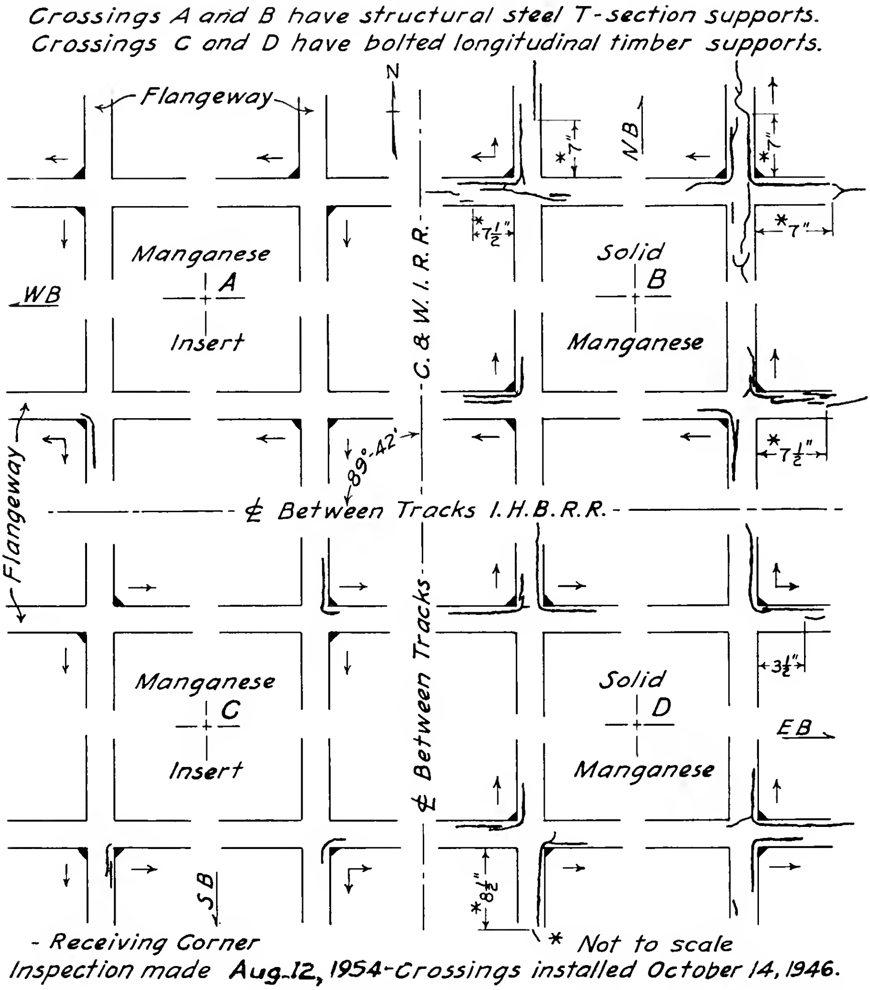


Fig. 1. - Flangeway Cracks in Four Crossings of the Chicago & Western Indiana R.R. and Indiana Harbor Belt R.R. near 55th Street and Cicero Avenue, Chicago, Illinois.

Installations in 1949

Because of failure of the welds in the original design of T-beam support, an improved design of support was fabricated for testing in the Elsdon Branch of the C&WI, located approximately 40 ft south of the southerly track in Fig. 1. Two solid manganese crossings (AREA Plan 771–40) were installed in May 1949 at the intersections of the Elsdon Branch with the two north and south tracks shown in Fig. 1. The steel-supported crossing was placed in the northward track, which has the greatest tonnage.

The inspection on August 12, 1954, revealed that the flangeway cracks in the steel-supported castings had increased considerably. During the last service year the aggregate length of the cracks increased from 53 in to 91 in. In addition, there was a 5-in crack in the top of the casting, mostly outside of the wheel path between the external arms of the NE corner. For the same period the flangeway cracks in the crossing on timber increased from 33 in to 55½ in. This excessive cracking of the castings on the steel support has probably been caused by an unstable roadbed which makes it difficult to keep it properly tamped. When the crossing is swinging it must bend more to get support, and this evidently sets up higher stresses in the castings at the critical areas. The clip bolts were all in place, but 40 percent were loose. It is difficult to keep the clip bolts tight because the dynamic loads on them are sufficient to permanently stretch the bolts. The improved design of T-beam support has shown no evidence of failure of the welds and is judged to be of sufficient strength for the service conditions.

Some of the tread corners of the castings on the steel support that had been welded were mashed down and will need repairs in the near future.

During th fifth year of service the cost of maintaining the crossings, as reported by the Belt Railway, was $279.47 for the steel-supported crossing and $59.80 for the crossing on timber. These figures include the cost of surfacing the steel-supported crossing six times and the other crossing once. The total maintenance costs for the 5-year period were $1074.89 and $261.16, respectively, for the steel and timber-supported crossings. The excess maintenance of the former crossing consisted principally of extra cost of surfacing, changing the stone ballast to a penetrated asphalt ballast, and repairs by welding.

Summary

The service tests of the 1946 crossings have indicated that the steel support was beneficial in the retardation of the formation of flangeway cracks in the insert crossings, but not in the case of the solid crossings. The four 1946 crossings have had good drainage, and the excess cost of maintaining the surface of the steel-supported crossings was moderate. The excess cost of lining the steel-supported crossings was much greater. The asphalt macadam ballast had the advantage of preventing muddy conditions.

The improved design of steel substructure used in the 1949 installations has adequate strength to carry the dynamic forces imposed on it by the traffic. The comparison of the performance of these two crossings has been distorted by the more difficult maintenance problems encountered with the steel-supported crossing. It has been impossible at that location to keep the last mentioned crossing properly supported, which is a prerequisite for obtaining the full advantage of the steel support.

In addition to last year's three recommendations for facilitating the maintenance of the steel-supported crossings (page 711, Vol. 55), it has been suggested to bolt treated hardwood timbers to the underside of the T-beam flanges so that the stones will become imbedded in the wood and resist dislocation by the impacts on the crossing.

Acknowledgement

The Association is indebted to the IHB and the Belt Railway for their splendid cooperation and assistance in the conduct of the service tests.

Appendix 3–c

Specifications for Spring Washers for Use in Special Trackwork

This is the final report on this research project, submitted as information, and it consists of two parts: (1) The results of a five-year investigation of the causes of loss in tension in frog bolts leading to specifications for spring washers for frog bolts, and (2) suggested specifications for spring washers for use on frog bolts.

Part 1

Crossing Frog Bolt Tension Tests

Digest

This investigation was made for the purpose of determining the reactive characteristics of spring washers required for the economical maintenance of adequate bolt tension in crossing and turnout frog bolts. Tests were conducted to determine the loss of bolt tension as related to the rate of wear of the crossing assembly during a five-year period under actual service conditions on six crossing frogs, including the bolted-rail, manganese insert, and solid manganese types, and one railbound manganese turnout frog. In addition, dynamic measurements were made of the change in bolt tension and impact or "shock" loads in the main bolts of a main track bolted rail crossing in high-speed territory. This is the first known thorough investigation of the loss in tension in frog bolts, and the causes thereof.

The service tests involved the measurement of bolt tension loss, pull-in or wear of the frog assembly, and nut back-off, all requiring specially designed gages. The test cycles included initial bolt tension of 40,000, 30,000 and 25,000 lb. Several kinds of single-coil washers, two designs of plate washers, and one shape of double-coil washer were tested with the 1⅜-in bolts in the main line crossing. The advantage of heat-treated nuts and hardened flat plate washers as bearing surfaces for the spring washers was investigated. Three designs of locknuts were included in the service tests.

Summary of Results

The more important results from these tests are summarized as follows:

1. In the bolted-rail and manganese insert types of crossings, the No. 1 position bolts (nearest to the flangeway intersection) lost, by far, the greatest amount of tension. This was attributed to a greater amount of wear of the crossing assembly at those bolts. The bolt tension measurements under traffic also indicated there were relatively large impact or shock loads on the No. 1 bolts of a bolted-rail crossing. This caused further dissipation of the tension by the spring washers imbedding into the nut and corner brace. Therefore, the chief causes of the loss in tension of frog bolts were found to be the wear of the crossing assembly and the imbedding and abrasion of the spring washers into the nuts and crossing braces, resulting from the larger shock loads on the bolts. Some of the larger shock loads increased the bolt tension from 40,000 lb (static) to 55,000 lb total. It was this excess load that caused indentation and abrasion on the small bearing areas of the spring washers. Bolt stretch and nut back-off were found to be unimportant as far as the dissipation of the bolt tension was concerned.

2. The use of hardened parts next to single-coil spring washers was beneficial in retarding the rate of loss in bolt tension for the medium reaction washers, but not for the high reaction washers. It is judged that more benefit would be derived if the corner braces in a crossing were heat treated, rather than adding a hardened flat plate washer next to the corner brace.
3. The double-coil spring washers tested held the tension in the No. 1 bolts above 20,000 lb twice as long as the single-coil spring washers. This increased efficiency was attributed to (1) the greater bearing areas provided by the double-coil type, and (2) the superior release curve.
4. The locknuts were found to be of no significant benefit in the retention of bolt tension. No locknuts backed off the bolts. None of the finger-free nuts backed off the bolts that had some remaining tension. These nuts did back off of some bolts with no tension, but in several instances such was not the case.
5. From the results of the service tests, it was found that (1) the initial tension should be 40,000 lb (plus or minus 5000 lb), and (2) the minimum tension should be 10,000 lb. The value of initial tension is the practical limit for manual wrenching, and the lower limit of 10,000 lb was determined from the service test measurements as that necessary to prevent excessive movement and wear between the parts of the crossing assembly.

Recommendation

The recommended test procedure and minimum reactive pressure for spring washers are as follows:

Place washer in the testing machine between steel plates having smoothly ground or machined surfaces and a Brinell hardness of not to exceed 150, which will provide bearing surfaces corresponding in hardness to the nuts and corner braces in crossings. Load assembly to 40,000 lb and take dial reading of the distance between platens of the testing machine. Increase load to 60,000 lb to include a simulated shock load of 20,000 lb. Release load to give the same dial reading as measured at 40,000 lb. From this point, release the platens 0.030 in additional, at which point the reactive load shall be not less than 10,000 lb.

Introduction

This investigation was initiated in 1948 for the purpose of determining the minimum reactive characteristics required of spring washers for economical and efficient maintenance of adequate bolt tension in crossing and turnout frog bolts. Because of the lack of information on the loss in tension in the main bolts of crossing frogs, a comprehensive series of field service tests was planned and executed. These service tests included seven crossing frogs of three types and one turnout frog. The field work involved the measurement of the loss in tension of the frog bolts, nut back-off, wear of the frog assembly, and observations of the effect of crushing of the nut and the side of the crossing arm by the several types of spring washers used. The causes for loss in bolt tension are: (1) wear of the assembled parts, (2) bolt stretch, (3) nut back-off, and (4) imbedding of the spring washers into the contact surfaces as a result of the shock loads. The field measurements gave complete information on the first three causes, but not for the fourth item because the imbedding effect could not be included in the out-to-out measurements of wear.

In the early stage of the field tests it was developed that bolts in certain positions lost a large amount of bolt tension, while others had only moderate reductions. Later, impact loads were measured in the main bolts of a bolted-rail crossing in high-speed territory. This test provided valuable information as to the cause of the variation in the loss in bolt tension with respect to bolt position and other practical aspects. The results of that test were published in the Proceedings, Vol. 54, 1953, pages 1002–1034. In the latter years of the field investigation, the primary objective was to determine how the dissipation of the bolt tension could be retarded by testing different types of spring washers and using hardened parts next to the washers. The first progress report covering the service tests was published in the Proceedings, Vol. 52, 1951, pages 532–553.

Test Procedure

In order to make the measurements on the frogs with long bolts, it was necessary to design a long caliper extensometer for measurement of the bolt tension, and an out-to-out gage to determine the wear of the parts of the crossing assemblies, and to revise the back-off gages for the large nuts. A second out-to-out gage was designed because consistent results could not be obtained with the original one which did not have a spring for holding it in place in order to eliminate the effect of variations in the technique of taking the readings. The bolt tension extensometer was similar to those used for track bolts and was entirely satisfactory.

Prior to beginning the service tests, a laboratory calibration of heat-treated 1¼-in and 1⅜-in diameter frog bolts of lengths from 8 to 18 in was made in a compression-tension testing machine to determine the bolt tension constants per dial division (0.0002 in) of the extensometer for effective bolt lengths ranging from 7 to 17 in. For the purpose of the measurement of bolt tension the effective bolt length is the distance from working face of the bolt head to the mid-thickness of the nut. This length was determined in the field with outside calipers.

At first, all cycles of bolt tension loss were conducted with 40,000 lb initial tension. Later, supplementary information was obtained for 25,000 and 30,000 lb initial tension during the summer cycles. It was found in the crossings that were two to four years old when the tests were begun in 1948, that 2-man wrenching was required to tighten some of the 1⅜ and 1¼-in diameter bolts to 40,000 lb, and later some bolts required 3 men. In the bolted-rail crossings carrying slow-speed traffic, it was necessary to renew some of the bolts because of battered threads which prevented wrenching them to 40,000 lb tension. At Warsaw, Ind., the test of the heat-treated bolted-rail crossing was started when the crossing was 14 months old. Most of the 1⅜-in by 14-in bolts could be tightened to 40,000 lb by 1 man. However, later some of the bolts required 2 men. It, therefore, was assumed that 40,000 lb bolt tension was the limit of practicality, because most frog bolt wrenching in track is done manually.

Spring Washers, Hardened Parts and Locknuts Used

Several designs of single-coil spring washers, one of the double-coil type and two designs of plate washers, were included in the tests to cover a wide range of reactive spring pressures, variations in the characteristic bearing areas of the three types of washers, and to check the capacity of each for retention of bolt tension. Release curves for all of the spring washers tested with the 1⅜-in and 1¼-in bolts are presented in Figs. 1* to 6, incl. Table 1* is included to give the dimensions and other physical properties of the washers. Initially, the Reliance Division, Eaton Manufacturing Company, furnished experimental single-coil spring washers for both sizes of bolts, but these are now included in their line of Improved Frog and Crossing Hy-Crome spring washers. These washers

* All figures and tables referred to in this report are represented at the end of the report.

are sometimes given the designation of wide bearing, because of their greater width. The same company, at the request of the AAR research staff, also furnished ¾-in square single-coil, high-reaction experimental spring washers for 1⅜-in bolts, known as "Heavy-Duty Hy-Crome". In addition, that company furnished a small lot of "Double Hy-Crome" washers for 1⅜-in bolts. These washers differ from the double-coil Thackeray in that the ends were bent inward. This feature provided two improvements over the Thackeray type, which was not included in the field tests: (1) a better release curve, and (2) less gouging of the bearing surfaces by the ends of the washer. Hubbard & Company furnished some experimental single-coil spring washers for 1⅜-in bolts, having a cross section larger than their Super Service line of washers. Erico Products, Inc., Cleveland, Ohio, furnished two designs of plate washers for 1⅜-in bolts—the type D–5 compression and the S–300 plate washers. Type D–5 consisted of five ⅛-in plates, cemented together and the S–300 was a single plate, 0.30-in thick. Each plate or ply was 3 in square and had a spherical shape. The Pennsylvania Railroad specifications for the 1⅜-in and 1¼-in spring washers tested stipulate a minimum reactive spring pressure of 300 lb when the washers are released from a load of 60,000 lb, 0.17 in and 0.15 in, respectively. The PRR washers have low reactive pressures.

During the first year of testing of the main line crossing, observations of the imbedding of the single-coil washers into the nuts and corner braces indicated that the medium and high-reaction washers imbedded deeper than the low-reaction washers. For the purpose of increasing the effectiveness of the spring washers by reducing the dissipation of bolt tension from imbedding, ASA heavy heat-treated medium-carbon nuts were obtained from the Oliver Iron and Steel Corporation, and heat-treated flat plate washers were specially made for use next to the corner braces. The hardened nuts had a Brinell hardness range from 250 to 300, and the flat plate washers had a hardness close to 400 Brinell. These hardened parts were tested in two corners of the eastward crossing at Warsaw, Ind. Before heat treatment the medium-carbon nuts ranged from 130 to 170 Brinell.

Locknuts were also tested on one of the manganese insert crossings and in the two bolted-rail crossings at Warsaw. Hexagon and square Elastic Stop Nuts, hexagon Security Nuts, and square MacLean–Fogg Unitary Nuts No. 3 were included in the field tests. All of the locknuts were made of low–carbon steel.

MAIN TRACK CROSSING AT WARSAW, IND.

Test Conditions

The crossing in which the bolt tension tests were conducted is in the eastward main of the double-track line of the Pennsylvania Railroad and a single-track branch line of the New York Central System, Warsaw, Ind. The PRR eastward main carried 18 million gross tons of traffic per annum, consisting of both passenger and freight trains operating at medium high speed. The NYC branch line had 2 million gross tons of freight traffic per annum which operated at speeds below 20 mph. In 1949, when the test was started, the PRR used both diesel and steam power, some of the latter being of the 4–4–6–4 type having four cylinders, divided drive and rigid frame. By 1953, when the field tests were concluded, little steam power was in use by the PRR. The NYC trains were hauled by moderate size steam locomotives, principally of the Mikado (2–8–2) type.

Both crossing frogs were of bolted construction, 3-rail design, with heat-treated 131 RE rail and flangeway fillers. Each crossing was supported on longitudinal timbers, consisting of three 7-in by 9-in creosoted oak ties bolted together, with a width of 21 in under the PRR rails, and stone ballast. The test included all of the 48 main or shoulder bolts, 1⅜ in by 14 in. At the beginning of the bolt tension test the eastward crossing had been in service 14 months. Fig. 7 is included to show the test conditions for the second cycle of loss in bolt tension. Figs. 8 and 9 show the special gages being used for measurement of bolt tension and pull-in of the eastward crossing at Warsaw.

Test Data

Tables 2 to 10, incl., give a summary of the measurements of bolt tension and pull-in of the crossing assembly and a description of spring washers, nuts, etc., used in each corner of the crossing for all of the nine cycles of loss in bolt tension conducted in the eastward crossing. In addition, most of the tables include information on the number of bolts having less than 20,000 and 10,000 lb final tension at the end of the test cycles. For good performance, a spring washer should first effect the minimum average loss in tension, and second, have the least number of bolts below a certain desired minimum bolt tension, which will be discussed later. Although these tests were conducted in one diamond which carried the same traffic, the condition of support of a corner, fit and state of wear of the assembled parts can affect the relative rate of loss in bolt tension in the four corners of a crossing. For the 4-year test period the total wear at the No. 1 bolts was the largest for the NE corner and the smallest for the SE corner.

Some data were taken for 25,000 and 30,000 lb initial bolt tension for comparison with 40,000 lb tension. In the first cycle (Table 2) the performance of the Type D–5 compression washers was the best, and the Hubbard washers were a little more effective in retaining the tension than the PRR low-reaction washers. In the second cycle (Table 3) the D–5 washers lost some of their effectiveness because at the end of the cycle, 9 out of 12 had one or more broken layers. The Hubbard and Heavy-Duty Hy-Chrome washers were about equal in performance. The PRR washers had the largest loss in tension. By this time it was quite well established that the bolts in the No. 1 position lost the greatest amount of tension, with the Nos. 2 and 3 following in the order named. The nuts and corner braces were examined for abrasion and imbedding. More imbedding was found at the No. 1 bolts than at the other positions. Likewise, more imbedding also occurred with the Hubbard and Heavy-Duty Hy-Crome spring washers than with the PRR washers. The Type D–5 washers provided a more favorable bearing area, and imbedding and abrasion were the least.

After this cycle, the latter washers were removed because of the excessive breakage and were replaced with the newly developed S–300 plate washers, 0.30 in thick. Also at the close of the second cycle, the locknut test was transferred from the eastward to the westward crossing. The locknuts were left in the SW corner of the eastward crossing because they were in better condition than the available used nuts. All of the locknuts were of low carbon, and it was desired to use medium carbon nuts in the bolt tension test to represent the practice of most of the Member Roads. The performance of the locknuts will be discussed in a separate section of this report. Because of the excessive nut imbedding by the Heavy-Duty Hy-Crome washers, ASA heavy M. C. nuts were placed on the SE corner, releasing the regular medium carbon nuts which were the PRR standard.

Table 4 gives a summary of the third cycle with the changes mentioned, but with 25,000 lb initial bolt tension. In this cycle the S–300 washers were best in performance and the high-reaction washers in the SE corner ranked second. The Hubbard and the PRR washers were equal as to tension lost in the No. 1 bolts, but the former were slightly better than the latter in the other two positions.

For the next cycle (Table 5) the nuts were changed for the experimental washers, as indicated in the table. This was for the purpose of increasing their effectiveness in holding up bolt tension, if possible. In this long cycle of 6.70 months with 40,000 lb initial tension, there was not much difference in the performance of the three kinds of single-coil washers. The S–300 washers were a little more effective in holding up bolt tension, particularly at the No. 1 bolts which had two washers nested normally. At the end of this cycle, 9 out of 16 of the S–300 washers were cracked. It was apparent that the heat-treated nuts did not increase the effectiveness of the Heavy-Duty Hy-Crome washers in the SE corner, because the washers had crushed the corner braces and dissipated about as much tension as in the second cycle, Table 3.

For the fifth cycle (Table 6), all of the crossing corners were provided with the ASA heavy medium carbon nuts, and in the SE corner they were heat treated. A second or improved lot of S–300 plate washers was furnished for the SW corner of the crossing. The improved S–300 washers were said to have improved metallurgy and heat treatment. In this cycle with 30,000 lb initial tension, the PRR washers were more effective than the Hubbard washers. There was no explanation for this other than the difference in support of the two corners, such as one corner swinging more than the other. The S–300 washers showed quite superior performance for the retention of the bolt tension for this 5-month cycle, and the Heavy-Duty Hy-Crome washers were the next best. No bolts in these two corners had less than 10,000 lb final tension. Two of the S–300 washers were cracked in this cycle.

Prior to starting the sixth cycle (Table 7), some hardened flat plate washers were made to use to eliminate the imbedding of the spring washers into the corner braces. This was the simplest procedure for conducting the test, because of the complications of providing heat-treated corner braces. The Heavy-Duty Hy-Crome and Hubbard washers were provided with the hardened plate washers and heat-treated nuts, as indicated in the table. The hardened parts improved the performance of the Hubbard washers, but not that of the Heavy-Duty Hy-Crome washers. The performance of the S–300 washers was slightly better than that of the Hubbard washers. However, the SW corner had the advantage of two S–300 washers placed back to back on each of the No. 1 bolts. In this cycle of 6.93 months, only 2 of the bolts with S–300 plate washers had final tension of less than 20,000 lb, as compared with 4 of the Hubbard washers. All bolts had a final tension of more than 10,000 lb, except 2 with PRR washers. The improved lot of S–300 washers had much less breakage than the first lot. In two cycles, or approximately a year's service, the first lot had 9 out of 16 cracked, compared with 3 out of 16 of the improved lot.

For cycle 7 (Table 8), the Reliance Double Hy-Crome spring washers were substituted for the S–300 washers in the SW corner, and the construction in the other three corners remained the same as in cycle 6. Because of the severe imbedding of the medium and high-reaction single-coil spring washers having quite small contact areas, it was decided to investigate the double-coil design which has larger bearing areas against the nut and corner brace. No hardened parts were used with the PRR washers as it was desired to use that corner as the basis of comparison. During this 4.61-month cycle, with initial bolt tension of 30,000 lb, the PRR washers had a loss in bolt tension of 46 percent, compared with 25 percent for each of the other 3 kinds of test washers. The double-coil washers, without hardened parts, performed as well as the medium and high-reaction single-coil spring washers with heat-treated nuts and hardened flat plates. In addition to the double-coil washers providing larger bearing areas on the nuts and corner braces, they had the best release curve (Fig. 2) from zero to 0.037 in release from a load of 30,000 lb.

In cycle 8, the Reliance Heavy-Duty Hy-Crome single-coil washers were retired from the test to make room for new Reliance Frog and Crossing Hy-Crome washers with the same hardened parts. It was planned to compare the latter washers with the Hubbard washers, both with hardened parts. The Hubbard washers were replaced with new ones of the same design so that the comparison would be on an equal basis. In addition, it was decided to take data on the No. 1 bolts at approximately 3-month intervals, except those with the double-coil washers. Because this was the first cycle of 40,000 lb initial tension with the double-coil washers, the bolts were not disturbed until the end of the cycle. Table 9, consisting of four parts, covers cycle 8. Parts 1, 2 and 3 of the table give a summary of the 3-month cycles for each No. 1 bolt having single-coil washers. In the first 3-month cycle (Part 1), the Hubbard washers performed the best and the PRR washers showed the largest loss in tension. All of the washers performed better in the second 3-month cycle (Part 2), and only 1 bolt out of 12 (1–E with PRR washer) dropped below 20,000 lb tension. Part 3 is the average of the two 3-month cycles, which shows that the 2 medium-reaction spring washers with hardened parts held the bolt tension above 20,000 lb. The PRR washers had 2 bolts in 4 with tension less than 20,000 lb. Part 4 of Table 9 gives a summary of the 6½-month cycle for the double-coil washers, and only the Nos. 2 and 3 bolts for the other 3 corners of the crossing. It will be noted that all bolts having the double-coil washers had a final tension in excess of 20,000 lb. The effectiveness of the double-coil washers in the retention of bolt tension was far superior to that of any single-coil spring washer with or without hardened parts. The average remaining tension of the No. 1 bolts with double-coil spring washers after 6½ months was 26,500 lb. This value is about the same as shown in Part 3 of the table for the single-coil spring washers with hardened parts for only 3 months' service. Table 10 includes data for cycle 9 for all 4 corners of the crossing for a period of 2⅔ months. Crossing wear was not measured for this short cycle. In this cycle the Frog and Crossing Hy-Crome washers with hardened parts and the double-coil washers performed better than the other washers. There was only 1 bolt having less than 20,000 lb final tension in the corner with PRR washers, and 2 bolts in the corner with the Hubbard washers.

Table 11 is presented to give a summary of all cycles of bolt tension loss in which 40,000 lb initial tension was applied. This table, in addition to ranking the spring washers in the four columns on the right, also can be used for conveniently appraising the value of the several washers as to retaining bolt tension, and the benefits of the hardened parts. The best comparison as to cycles can be made from the even numbered cycles, which included a winter season. Prior to the fourth cycle, the PRR and the Hubbard washers were reversed as to corners to determine what effect the change in location would have on the loss in tension. The effect on all bolts with the PRR washer was to reduce the average tension loss from 62 to 51 percent. The average tension loss for all bolts with Hubbard washers increased from 50 to 53 percent. The benefits derived by adding the heat-treated nuts and hardened flat plates can be judged by comparing cycles 4 and 6. In the case of the Hubbard washers, tension loss in the No. 1 bolts dropped from 60 to 46 percent, or a reduction of 23 percent. For all bolts, the corresponding percentages were 53, 39, and 26 percent. The same comparison for the Reliance Heavy-Duty Hy-Crome washers for the No. 1 bolts was a drop from 65 to 56 percent, or a reduction of 14 percent. For all bolts there was no change in the percentage loss of bolt tension, this being 50 percent in both cycles. For the S–300 plate washers, cycles 4 and 6 showed for all bolts a drop in percentage loss from 46 to 36 percent, or a reduction of 22 percent, in favor of the second, or improved lot of washers. A part of this increased effectiveness may be attributed to the improvement in the manufacture of the washers, resulting in less breakage, and also because in cycle 6 the No. 1 bolts had two washers nested back-to-back, which was more effective in retaining bolt tension than with two washers nested normally as in the fourth cycle.

In the columns at the right of Table 11, the ranking percentages are based on the performance of the PRR washers without hardened parts. The performance of the double-coil washers for all bolts (last column) was outstanding in that the tension loss was less than one-half of that of the control washers. The next most effective washers were the S–300 with 77 percent, and type D–5 washers, 79 percent. Hubbard washers had a percentage of 87 and the Heavy-Duty Hy-Crome washers, 96 percent.

PENNSYLVANIA RAILROAD–GULF, MOBILE & OHIO RAILROAD CROSSINGS AT CHICAGO

Test Conditions

These crossings are of construction similar to those at Warsaw, Ind., except the rail is the 130 PS section, and the main bolts did not have a drive fit such as was the case of the eastward crossing at Warsaw. The two diamonds selected for bolt tension tests (Fig. 10) are in the PRR eastward "Panhandle" track and the double-track main line of the GM&O, near 37th St. and Campbell Ave., Chicago. The PRR traffic, amounting to approximately 4 million gross tons per annum, was slow-speed yard freight movements between their 59th St. yard and various industries and interchange points. The GM&O traffic included passenger and yard freight movements. All movements over the crossings were hauled by diesel locomotives, except some steam power was operated by the PRR. Most of the traffic was operated at slow speed because all trains were required to stop at the crossings. The rear portion of some of the long GM&O passenger trains attained speeds up to 30 mph. In 1952 the GM&O estimated its annual gross tons of traffic at 4.2 and 4.8 million for their northward and southward tracks, respectively. The crossings were supported by longitudinal bolted creosoted oak timbers under the PRR rails, and stone ballast. These crossings were installed by the PRR in September 1944.

Test Data

In crossing "C" (Fig. 10), the PRR specification spring washers were compared with the Hubbard experimental washers like those tested at Warsaw. In crossing "D", the Reliance Frog and Crossing Hy-Crome washers were compared with the PRR washers. All tests were made with the ASA regular, medium-carbon nuts and 1⅜-in by 14-in bolts already in use in the crossings. Two cycles each of 40,000 lb and 25,000 lb initial bolt tension were conducted, and the results are summarized in Tables 12 to 15, incl. Cycle 1 (Table 12) covered four months' service with 40,000 lb initial tension, and cycle 2 (Table 13) was for a longer cycle to develop the capacity of the spring washers for retaining tension over a long period. In cycle 1, the special test washers were slightly more effective than the PRR washers. The medium weight washers were the most effective for the bolts in the No. 1 position. In crossing "C", the Hubbard washers had only 3 bolts with less than 20,000 lb final tension, compared with 7 for the PRR washers. In crossing "D", the PRR washers had only 1 bolt with less than 20,000 lb tension, compared with 4 for the Frog and Crossing Hy-Crome spring washers. Cycle 2 (Table 13) was too long for good maintenance of bolt tension, but it served the purpose of giving the washers a more severe test. The special washers averaged 53 percent tension loss, compared with 61–62 percent for the PRR spring washers. In each half of each crossing over one-half of the bolts dropped below 20,000 lb tension. In each crossing, the special washers permitted fewer bolts to drop below 10,000 lb tension. Cycles 3 and 4 (Tables

14 and 15) were made with 25,000 lb initial bolt tension to develop information on the use of low bolt tension. Initial tension of 25,000 lb was decidedly inadequate for these long test cycles in which many of the bolts dropped below both 20,000 and 10,000 lb tension. In crossing "C" (Table 14), the PRR washers lost 43 percent tension, compared with 46 percent for the Hubbard washers. In crossing "D", the Frog and Crossing Hy-Crome washers were more effective in retaining the bolt tension than the PRR washers. In Table 15 the Hubbard washers had the lowest percentage loss in tension.

CHICAGO AND WESTERN INDIANA RAILROAD AND INDIANA HARBOR BELT RAILROAD BELT LINE CROSSINGS AT CHICAGO

Test Conditions

The four crossings shown in Fig. 11 were installed by the IHB in October 1946 for the purpose of conducting service tests with the solid and reversible insert manganese types of frogs, supported by longitudinally framed timbers on stone ballast and integrally welded steel T-beam substructures on asphalt macadam ballast. Crossings "A", "C", and "D" were selected for conducting bolt tension tests. Crossing "A", with a steel substructure, was included for comparison with crossing "C" on timbers to determine if the difference in the crossing supports would influence the loss in tension of the main bolts in these insert crossings. The continuous timbers for crossings "C" and "D" were placed under the IHB rails. Solid manganese crossing "D" differed from AREA Plan 771 in that the castings were made so that the guard and running rails abutted the external arms in the same plane, instead of having an offset between the two junctions. The castings also had integrally extended bottom plates. All of the joint bars for the external and internal joints were of the machined type, and the outer bar for each external joint was sloped on top to serve as a riser for the wheels. The castings were 6 in high to match the 105-lb Dudley rail section, which was also used in the insert crossings. All of the main bolts in the two designs of crossings were 1¼ in diameter, except the internal bolts of the solid crossings were 1⅜ in diameter.

The traffic consisted largely of interchange freight movements, hauled by diesel and steam power at first, with a gradual conversion to diesels. Most of the traffic operated at moderately slow speeds, except some of the north and south movements ranged up to 30 to 35 mph. The tonnage on the two tracks of the IHB was said to be about equal, and the northward C&WI track (operated by the Belt Railway of Chicago) carried more tonnage than the southward track. Therefore, the two insert crossings carried about the same tonnage during the test period, and the two solid crossings had a greater tonnage.

During the first four cycles a test was made in crossing "A" with hexagon Elastic Stop Nuts in the west half of the crossing, with and without spring washers, as indicated in Fig. 11. However, for the fourth cycle, the washers were moved from the SW to the NW corner. These results will be discussed later. At the beginning of these tests all of the spring washers were second hand except in the west half of insert crossing "C". Through an error, 1⅜-in washers were furnished for the 1¼-in bolts. The washers were replaced with the correct size at the beginning of cycle 3. At the beginning of cycle 4, new Standard Hy-Crome spring washers were placed in the east half of crossing "C" to obtain a comparison between new spring washers of two weights. At the same time new nuts were placed on all bolts, and all of the beveled washers and headlocks on the bolts were spot welded to the corner braces to prevent them from twisting when wrenching the bolts (thereby fouling points for measurement of pull-in), and to reduce the eccentric load on the bolts which may have dissipated tension by the spring washers imbedding into the nuts and beveled washers.[1] No change was made in the spring washers in crossing "D" and in the east half of crossing "A", except to replace broken ones with used ones of the same design, as indicated in Fig. 11.

For the three crossings, a preliminary tension loss cycle was conducted from October 1948 to April 1949, before it was possible to secure reliable data on crossing wear or pull-in. A second gage with spring tension to hold it in place was developed and it proved satisfactory. The preliminary test was made with 40,000 lb initial bolt tension, and crossings "A" and "C" had the same loss in tension, or 56 percent. These data indicated the bolts in the insert crossings lost from 79 to 89 percent tension in the No. 1 position. The corresponding values for the Nos. 2 and 3 positions were 45 to 70 percent and 6 to 28 percent, respectively. As in the bolted-rail crossings, this indicated that the No. 1 bolts in the insert crossings lost the greatest tension and constituted the major problem in maintaining adequate bolt tension. In crossing "C" the average loss in tension of all bolts with the Frog and Crossing Hy-Crome washers was 52 percent, compared with 59 percent for the lighter weight used Standard Hy-Crome washers. In crossing "D", solid manganese on timbers, the exterior 1¼-in bolts lost 65 percent tension and the 1⅜-in interior bolts lost 69 percent tension. In the external arms, the No. 1 bolts nearest to the flangeway intersection lost the largest amount of tension and the bolts in position 4 had the least loss in tension. In the 6-hole interior joints, the middle and intermediate bolts, Nos. 3 and 2, lost the most tension and the No. 1 bolts in the end position showed a smaller loss in tension.

The next cycle, designated as No. 1, was also conducted with 40,000 lb initial tension and extended from June to November 1949, or about 5 months. The average loss in tension for all bolts in the insert crossings was 31 percent for "A" on the steel substructure, and 26 percent for "C" on framed timbers. In crossing "C", all bolts with the used Standard Hy-Crome washers lost an average of 27 percent tension, compared with 25 percent for the Reliance Frog and Crossing washers. The latter washers were of the 1⅜-in size on 1¼-in bolts, which probably detracted from their effectiveness because of the loss of bearing area next to the periphery of the bolt. Crossing "D", solid manganese on framed timbers, had an average loss in tension of 32 percent for all bolts and the same percentage also applied to both the exterior and interior bolts. The pattern of percentage loss in tension of the bolts by position was quite similar to that for the preliminary cycle. In both of the foregoing cycles, the tension loss was greater in the solid crossing than that of the insert crossing "C", both being supported on timbers. However, it cannot be concluded that the solid type of crossing dissipates bolt tension more than the insert type because the former carried more traffic by being in the northward track.

The results of cycle 2 (40,000 lb initial tension) for the three crossings were published in the Proceedings, Vol. 52, 1951, pages 546-551. The data indicated for this 8-month cycle an average loss in tension of 45 percent for the insert crossing on steel support, compared with 32 percent for the insert crossing on timber. In crossing "C", the Frog and Crossing Hy-Crome washers showed an average loss in tension of 26 percent, compared with 38 percent for the used Standard Hy-Crome washers, or a reduction of 32 percent loss by the former, which were for 1⅜-in bolts. Crossing "D" had an average loss in tension of 40 percent for all bolts and 42 and 38 percent for the interior and exterior bolts, respectively. The tension loss pattern for the internal joints was similar to a 6-hole joint in that the middle bolts lost the most tension and the end bolts the

[1] In the insert-type crossing, only the Nos. 1 and 2 bolts had beveled washers and headlocks. Since the inception of this investigation, Ramapo Ajax has adopted the practice of forging in one piece the washers and headlocks for the Nos. 1 and 2 bolts.

least. In the case of the external joints the loss in tension decreased by bolt positions 1, 3, 2, and 4. In the last-mentioned reference to the Proceedings, graphs of final tension and pull-in were presented for the two insert crossings. The plotted points in these graphs were not in good agreement with the combined release curves for the spring washer used and the bolt. Later it was determined that (1) the spring washer release curve taken on simulated bolted-rail construction parts was well below that taken on hardened blocks, and (2) an appreciable amount of bolt tension was dissipated by the shock loads[1] on the bolts, which caused the spring washers to imbed into the nuts and the side of the crossing assembly. The effect of this imbedding was not included in the pull-in measurements because the wear measurements were made from out-to-out of corner braces or joint bars. Consequently, it was decided to discontinue the graphical presentation.

Tables 16 to 22, incl., are presented to cover the remainder of the field tests conducted on the three Belt Line crossings. Cycle 3, with 25,000 lb initial tension, was too long for good maintenance of the insert crossings, but it did give the washers a more severe test. Crossing "A" lost an average of 41½ percent tension and the corresponding figure for crossing "C" was 54½ percent, for a period of 9 months, ended April 1951. This was the first cycle in which the west half of crossing "C" had 1¼-in Frog and Crossing Hy-Crome washers, replacing those for 1⅜-in bolts. In the upper portion of Table 17, it will be noted that the latter washers dropped in effectiveness. Those bolts lost 53 percent tension, compared with 56 percent for the used Standard Hy-Crome washers. Upon inspection of the imbedding of the washers into the nuts, it was found that the previous 1⅜-in washers had worn a collar on the nut and the 1¼-in washers had imbedded into the collar, which increased the loss in tension. Crossing "D", for a 6-month cycle, lost an average tension of 34½ percent, or 37 and 32 percent for the interior and exterior bolts, respectively. With only 25,000 lb initial tension, the interior bolts in the 3 positions lost approximately the same percentage tension, which was a departure from the previous pattern similar to a 6-hole track joint.

In cycle 4, Tables 18 and 19, crossings "A" and "C" were tested with 30,000 lb initial tension for different lengths of test periods. The insert crossing on the steel support lost 41½ percent tension in 6.4 months, and the crossing on timber lost 28½ percent in 5 months. Prior to cycle 4 for crossing "C", new nuts were applied to all main bolts, new Standard Hy-Crome washers were applied to the east half of the crossing and all beveled washers and headlocks were spot welded to the corner braces for reasons previously stated. In this crossing, bolts with the Frog and Crossing washers lost 24 percent tension, compared with 33 percent for the new Standard Hy-Crome washers, or a reduction of 27 percent. The medium weight washers were most effective for holding up the bolt tension in the No. 1 position—the critical one. Solid manganese crossing "D", with initial tension of 25,000 lb (Table 19), had too many bolts below 20,000 and 10,000 lb final tension. The cycle was too long because the bolts in each group lost their normal loss in tension pattern and tended to equalize the tension loss in each group. After cycle 4, tests were discontinued with the insert crossing on steel support (Crossing "A").

In cycle 5 (Table 20), initial bolt tension of 40,000 lb was used in crossings "C" and "D" for periods of 6.7 and 7.6 months, respectively. Relative percentages of loss in tension were 34 and 62½, respectively. In crossing "C", the Frog and Crossing washers were slightly more effective in retaining the tension than the Standard Hy-Crome washers. This difference was entirely for the No. 1 bolts. Because of the long cycle the

[1] The report on the Measurement of Shock Loads in Crossing Frog Bolts was published in the Proceedings, Vol. 54, 1953, pp. 1002–1034.

two groups of bolts in crossing "D" departed from their normal pattern of loss in tension, although it was slightly evident for the interior bolts. Only 2 bolts in crossing "C" dropped below 10,000 lb tension, compared with 12 for crossing "D".

Cycle 6 (Table 21) was conducted with 30,000 lb initial tension for crossings "C" and "D", for a period of 4½ months. Crossing "C" lost only 16 percent tension compared with 40 percent for solid crossing "D". In crossing "C" the Frog and Crossing washers held the tension loss to 14 percent, compared with 18 percent for the Standard Hy-Crome washers, and the number of bolts having less than 20,000 lb final tension were 3 and 6, respectively. No bolts dropped below 10,000 lb. The pattern of loss in tension of the interior bolts of crossing "D" was in good agreement with that of a 6-hole track joint in that the loss in tension was greatest at the middle bolts (No. 3) and smallest at the end bolts. A much larger number of bolts in the solid crossing dropped below 20,000 lb tension than in the insert crossing on timbers.

Table 22 gives the results of cycle 7 for solid crossing "D" with 40,000 lb initial tension and a service period of 6½ months. In this cycle the exterior bolts lost more tension than the interior bolts. However, considering all test cycles, the average tension lost was about the same for each group. Eleven out of 24 internal bolts and 20 out of 32 external bolts dropped below 20,000 lb tension. One interior and 5 exterior bolts had final tension under 10,000 lb.

Bolt Tension Loss Patterns of Three Types of Crossings

It will be of interest to compare the patterns of tension loss of the three designs of crossings and the effect of operating conditions on two or more crossings of the same type. A typical cycle of loss in tension from 40,000 lb, including a winter season, was selected for each of the six crossings involved in the measurements of tension loss. This information is presented in Fig. 12. The numbers in the circles are the losses in tension expressed in percent of the initial tension of approximately 40,000 lb. At Warsaw the entire crossing lost 50 percent tension, with 61 and 39 percent loss in the PRR and NYC rails, respectively. The ratios indicate that the bolts in the PRR rails lost 56 percent more tension than in the NYC rails. The external bolts lost less than the internal bolts. At that location the PRR traffic was 9 times as heavy as the NYC, and the greater tension loss quite logically occurred in the PRR rails, although they were favored with the longitudinal timber support.

At the 37th St. location with the same type of crossing as at Warsaw, the tension loss patterns were quite different with respect to the support. The tonnage over each side of the two crossings was about equal. The tension loss in the GM&O rails was 26 percent greater than in the PRR rails, which were favored by having the supporting longitudinal timbers. The outstanding feature of these crossings was the heavy loss in tension of the GM&O external arms, being 45 to 58 percent greater than the values for the PRR external arms. Likewise, in the GM&O rails, the external bolts lost 46 to 51 percent more tension than the internal bolts. The external bolts in the GM&O rails had the greatest loss in tension of any of the arms. At that location equal support of the two sides of the crossings would be beneficial in reducing the tension loss in the GM&O rails, particularly in the external arms.

At the 55th St. location, the two manganese insert crossings had about the same amount of traffic, because both were in the southward track of the C&WI, and the two IHB tracks were said to have about the same tonnage. For both crossings, the ratios, IHB/C&WI rails, were close to unity, except the first and third listed ratios were greater for crossing "C" on a framed timber support. It is significant to note that the three ratios, external/internal bolts, for crossing "A" on the steel support, were close to unity, while those for crossing "C" on timber were approximately 1.50. Although the steel support was not beneficial in retarding the tension loss of all bolts, compared with that of crossing "C", the steel support did tend to equalize the tension loss in the external and internal arms of both tracks. In another cycle analyzed (30,000 lb initial tension), this beneficial equalization of the loss in the IHB rails was remarkable. The ratio of the tension loss, all external/internal bolts, was 1.92 in crossing "C" on timber, compared with 1.06 in crossing "A" on the steel support. In solid manganese crossing "D" the bolts in the C&WI rails lost 13 percent more tension, which difference was entirely due to the excess loss in the internal bolts. The percentage loss in all external bolts was about the same as the internal bolts.

Turnout Frog Bolt Tension Tests

A main line turnout frog was included in the bolt tension tests to develop some information on the rate of loss in bolt tension of this type of frog. The PRR very kindly permitted the AAR research staff to conduct tests on a No. 15, 25-ft railbound manganese frog with 140 PS rail in the westward main and crossover, immediately east of the crossings at Warsaw, Ind. This crossover was controlled by the interlocking plant at the crossing. The turnout was installed new in the spring of 1949, and the test was started in May 1950. This was a trailing turnout for westward movements, and the PRR traffic was similar to that previously described for the eastward test crossing.

All of the 18 bolts, 1⅜ in diameter, were included in the measurements. Thirteen of the bolts were replaced with longer ones, with extra threaded length, in order to reduce the number of lengths from nine to three for the purpose of simplifying the bolt tension measurements. In the railbound frog construction, the bolt heads were clamped against malleable iron beveled headlock washers shaped to fit the web of rail, and the spring washers were in contact with similar beveled washers without the headlock. All of the bolts had ASA regular medium-carbon nuts. The field measurements consisted of bolt tension loss, pull-in or wear of the frog assembly, and nut back-off, the same as for the crossing tests.

Three cycles of loss in bolt tension with 40,000 lb initial tension were conducted with two weights of washers for service periods ranging from 0.90 to 1.28 years. The first cycle was conducted with the PRR specification washers, and the other cycles included the Frog and Crossing Hy-Crome washers that had been in service for less than two years in one of the IHB–C&WI crossings being tested at the 55th St. location. The data for each test cycle are presented on a plan of the frog and in a table. Fig. 13 and Table 23 cover the first cycle of loss in tension, with an average loss of 23 percent for a period of 1.28 years. The second cycle was the first one in which the Frog and Crossing Hy-Crome spring washers were tested (Fig. 14, Table 24). The average tension loss for all bolts for a service period of 1 year was 29 percent, compared with 23 percent in the first cycle with the PRR specification washers. Cycle 3 (Fig. 15, Table 25) gave an average loss in tension of 22 percent with the medium weight washers for 0.90 year of service. The latter washers were not as effective in cycle 2 as in cycle 3, because of being placed against bearing surfaces which had been indented and abraded by the low-reaction washers having a much smaller width. In other instances the wide bearing washers dropped below expectations when first substituted for narrow washers on the crossing frogs.

In the three cycles, only bolt 9H in cycle 2 dropped below a final tension of 20,000 lb. This was influenced to some extent by not having the full 40,000 lb tension initially.

It will be observed from the figures and tables that bolts in certain positions lost more tension than the others. Taking the average tension loss of the three cycles, bolts 5T and 4T ahead of the frog point, and bolts 3H, 4H, and 6H behind the point lost the greater amounts of bolt tension in their respective groups. Bolts 5T and 4T are located near the toe end of the casting near the first bend in the rails from the toe of the frog. Bolts 3H and 4H are near the heel end of tread wings of the casting, near the receiving end of the casting tread for trailing main line movements (to the left in the figures). Bolt 6H was near the junctions between the running rails and the casting where its width was reduced to accommodate those rails. Bolts losing the next largest amount of tension were 2H, 5H, 8H, 9H, 11H, and 13H. Prior to these tests the PRR section foreman had indicated bolts 5T, 4T, 3H, 4H, 5H, 10H, and 11H had required the most wrenching in this design of frog.

The values of pull-in for the turnout frog tests had considerable scatter and some inconsistencies with respect to the amount of tension lost. It seems logical in this type of construction, where adjoining bolts lost widely different amounts of tension, that the horizontal flexure of the rails, caused by the irregularity of the final tension values, could partially offset some of the pull-in at points of the larger losses in tension, and possibly increase it at points of low losses in tension.

This test has indicated that with reasonably new frogs of this design and good maintenance, the problem of maintaining bolt tension is a minor one compared with that of crossing frogs under comparable service conditions. It is judged that maintaining adequate bolt tension in turnout frogs of bolted-rail construction, with or without high guards, in heavy-duty side tracks with a lower standard of maintenance, will require more frequent retightening of the frog bolts than in the test frog. Because of the slow rate of loss in bolt tension in the test frog, it seems logical to conclude that impacts imposed on the bolts by the traffic are much smaller than was measured in the No. 1 bolts of the westward crossing at Warsaw.

TESTS OF LOCKNUTS

Three types of locknuts were included in these tests to develop information on their utility and influence upon the maintenance of crossing frog bolt tension. All of the locknuts were made of low-carbon steel. Each had a different principle of providing thread friction for holding the nut in place. The Elastic Stop Nut was of the interference type in which the locking element was a compressed fiber collar insert locked in the crown side of the nut. As the nut was wrenched on the bolt, the threads on the bolt cut threads in the collar which provided thread friction. The Security locknut utilized an alloy steel threaded retainer in the crown of the nut which was made elliptical in shape to provide thread friction by having the retainer assume a round shape when the nut was wrenched on the bolt. The MacLean–Fogg Unitary Nut No. 3 had the top two or three threads deformed slightly out of a true helix to provide thread friction for locking itself in place.

Bolt Tension Tests

The first test conducted with locknuts was in the west half of crossing "A" (Fig. 11), which was the manganese insert crossing supported by the structural steel substructure and asphalt macadam ballast, at the 55th St. location. In the preliminary cycle and cycles 1, 2 and 3 (all with 40,000 lb initial tension, except No. 3, which had 25,000 lb), the northwest corner of the crossing had hexagon Elastic Stop Nuts for the 1¼-in bolts without spring washers and the southwest corner had the locknuts with used Hy-Pressure Hy-Crome spring washers. For cycle 4, with 30,000 lb initial tension, the spring washers were moved to the northwest corner of the crossing to determine if the service conditions were different in the two corners. In the preliminary cycle the corner with locknuts and without washers lost 47 percent tension, compared with 55 percent for the other corner with locknuts and spring washers. The corresponding figures for cycle 1 were 30 and 35 percent, and for cycle 2, 46 and 47 percent. Thus, a slight advantage was shown for the corner without spring washers at first, and this had practically disappeared in cycle 2. This small advantage of the locknuts without washers was influenced by the fact that there were no washers to imbed into the nuts and corner braces as a result of the shock loads, principally on the No. 1 bolts which lost the most tension. Also, the low-carbon locknuts were more easily indented by the spring washers than in the case of the medium-carbon nut generally used on frog bolts. The results for cycles 3 and 4 are given in Tables 16 and 18. In Table 16 for cycle 3, with 25,000 lb initial tension, the corner with the locknuts and no spring washers lost 52 percent, compared with 39 percent in the southwest corner having the locknuts with spring washers. After moving the washers to the northwest corner for cycle 4, the percentages were 39 and 45, respectively, in favor of the northwest corner with the washers and locknuts. This test demonstrated that the locknuts remained in place with or without washers, but were of little value in retaining bolt tension throughout their service life.

The second bolt tension test with the three types of locknuts was made in cycles 1 and 2 of the eastward crossing at Warsaw, Ind. Fig. 7 shows the location of the locknuts in three corners of the crossing, all being used with the washers indicated in the figure. In each of these test cycles there was no significant difference in tension loss of the bolts with the locknuts and those with the medium carbon nuts. After completion of cycle 2, the three types of locknuts were placed in three corners of the westward crossing for further observations and to liminate the low-carbon nuts from the bolt tension test, because medium-carbon nuts were in general use on crossing frogs. In this test the bolt threads were oiled each time the tension was checked, and no trouble was experienced with the locknuts becoming frozen.

Service Test

This service test was started May 1, 1950, and terminated July 7, 1953. The bolts were retightened with the same frequency as in the eastward crossing. A record of the nut back-off was maintained. No measurements of bolt tension were taken in this test with locknuts. When the locknuts were first applied to the three-year old bolts, the bolt threads were not oiled. By August 1952, the bolts with the Security and Unitary No. 3 locknuts were very hard to wrench. To facilitate the bolt maintenance, the locknuts were removed and reapplied after oiling the bolt threads. Table 26 is included to give a record of the frictional torque required to wrench the nuts on the bolts twice. In the first application, several of the Security and Unitary No. 3 locknuts developed high friction torque because of damaged threads at the end of some of the bolts. All three types of locknuts lost a large proportion of their frictional torque in the reapplication with lubrication. A few of the nuts were finger free.

During the service tests it was difficult at times to wrench some of the Security and Unitary No. 3 locknuts. As a result of the large torque required, the headlock bars welded to the corner braces were damaged. With large frictional torques, it was difficult for two men to retighten the bolts. Some of the headlock bars on the corners having the two last-mentioned types of locknuts had been broken or bent. This made it necessary in retightening the bolts to use two wrenches, an additional one being required to hold the bolt head. All locknuts were removed and replaced with the PRR standard nut (ASA regular medium carbon) in July 1953. At that time it was difficult to remove some of the two last-mentioned types of locknuts.

There was no backing off of the locknuts in any of the tests. The locknuts were not beneficial for maintaining bolt tension, except that in one of the insert crossings where one type of locknut was tested with and without washers, there was a temporary advantage when no spring washers were used. A uniform bolt tension cannot be obtained with locknuts because of the wide variation in frictional torque. Because of the large torque required to wrench some bolts with locknuts, adequate bolt tension cannot always be applied with two men on a wrench. It is possible for locknuts to conceal that frog bolts have lost all tension and are no longer performing their primary function.

DISCUSSION OF TEST RESULTS

Accelerated Initial Loss of Bolt Tension

From the previous investigation of the loss in bolt tension in track joints, it was known that after tightening bolts, the loss in tension in the first few days was large as compared with the remainder of the service period. The crossing bolts were checked to ascertain the magnitude of this early loss in tension.

In crossing "C" (Fig. 10), at the 37th St. location, the loss in six bolts was checked for one day as follows:

Initial Tension 40,000 lb

Bolt Position	*Percent Tension Lost*	
	First Day	*8 Months*
SW Frog—PRR Specification Washers GM&O External Arm		
1W	28	100
2W	27	84
3W	32	63
Avg.	29	82
SE Frog—Hubbard Exp. Washers GM&O External Arm		
1E	37	45
2E	30	74
3E	33	46
Avg.	33	55

Bolts with PRR washers lost in one day a much smaller proportion of the 8-month total than the Hubbard washers with higher reaction. This was probably influenced by the shock loads causing a greater initial indentation in the case of the heavier washers. For the 8-month period, the Hubbard washers lost one-third less tension than the PRR washers. There was no back-off of the nut on bolt 1W, which lost all of its tension.

In the eastward crossing at Warsaw, an overnight check was made of the loss in tension of bolt 1E in the PRR external arm of the SE corner with a Reliance Heavy-Duty Hy-Crome washer (Fig. 7). The overnight loss in tension from 40,000 lb was 36 percent compared to 60 percent for the test cycle of 7 months.

From the results of the field measurements of the dynamic shock loads on the bolts and the laboratory imbedding tests with shock loads, it is evident the high initial loss in tension in track was caused by the larger of the shock loads occurring during the short period.

Tension Loss by Bolt Position

A review of the tension loss tables will reveal that bolts in certain positions of the three types of crossings lost more tension than in the other positions. The bolt tension loss patterns for the bolted-rail and manganese insert crossings were similar in that the No. 1 bolts, nearest to the flangeway intersection, lost the greatest amount of tension; the No. 2 bolts, next in magnitude; and the No. 3 bolts the least. It was found in the measurements of the shock loads in the bolted-rail crossing at Warsaw that the shock loads were relatively large at the No. 1 position and quite moderate at the Nos. 2 and 3 positions, the latter being of the magnitude comparable with the bolts in a track joint. Consequently, the major problem of maintaining the bolt tension is at the No. 1 position. However, in several instances some of the Nos. 2 and 3 bolts deviated from the foregoing pattern and actually lost a greater tension.

It was determined for the solid manganese type crossing tested that in the 6-hole internal joints the middle bolts lost the greatest amount of tension and the end bolts the least. In the case of the 4-hole external joints, the two bolts in the receiving end of the casting or rail lost slightly more tension. These patterns of tension loss for the solid type of crossing were not as pronounced as those for the other two designs tested, and it seems unnecessary to retighten the bolts that lost the larger amounts of tension more frequently than the others in this type of crossing.

Rate of Bolt Tension Loss Per Month

A comparison of the rate of tension loss per month in all of the main bolts of the three types of crossings was made by selecting two typical long cycles (40,000 lb initial tension), averaging six to seven months' duration. The rate of loss was 7.6 percent for the bolted-rail crossings at Warsaw and the 37th St. location. At the 55th St. location, the insert crossing on steel support lost 5.9 percent per month, compared with 4.6 percent for the same type of crossing on framed timbers. The solid crossing at the same location lost 5.7 percent tension per month.

The most significant finding from these values is that under comparable traffic and maintenance conditions, the bolted-rail type of crossing would dissipate the bolt tension more rapidly than the other types.

The comparison between the two insert crossings at the 55th St. location was reasonably good as to traffic conditions. However, the diamond on steel T-beams was handicapped as to the spring washers and the locknuts without washers. The crossing on timbers was favored with special washers in one-half of the diamond. From the results obtained, it seems justifiable to conclude that, for the test conditions, the structural steel substructure was not beneficial as to retarding the dissipation of tension in the main bolts. If it had been possible to keep the diamond rigidly fixed to the steel support, the downward flexure of the crossing under the passing wheels would have been reduced. This lesser flexure would decrease the severity of the shock loads on the main bolts, particularly in the No. 1 position, and reduce the attendant loss in tension.

Because the solid crossing at the 55th St. location carried more traffic than either of the two insert crossings, it cannot be said with certainty that under comparable conditions the solid crossing would have the higher rate of loss in tension. It seems probable, under identical conditions of traffic and maintenance, that the insert type on timbers would lose the greater tension for a given tonnage.

Using the same test cycles to determine the monthly tension loss for the No. 1 bolts only, the following percentage values were obtained: Bolted-rail crossings—Warsaw, 9.4, 37th St. location, 10.5; insert crossings on steel support, 9.4, and on timber 6.4. The corresponding percentages for the Nos. 2 and 3 bolts in the same cycles were, respectively, 6.6, 6.2, 3.8 and 3.5. The foregoing comparison demonstrates the relatively high rate of tension loss of the No. 1 bolts with respect to the other two positions in bolted-rail and insert types of crossings. The latter group of percentages shows that the rate of tension loss in bolts 2 and 3 of the two insert crossings was about the same. The excess loss in tension of the bolts in the insert crossing on the steel support was primarily in the No. 1 bolts. Apparently, the steel-supported crossing flexed more under wheel loads than the insert crossing on timber, and the shock loads were higher, causing more dissipation in the tension of the No. 1 bolts. It was developed in the shock load tests at Warsaw that when the crossing settled two days after a rain, the maximum shock loads on the No. 1 bolts suddenly increased from 13,000 to 17,000 lb (initial tension 40,000 lb), because of the greater downward flexure of the diamond.

Thus, it has been shown that the bolted-rail crossings were highest in the rate of loss in tension, and the No. 1 bolts in that type of crossing, as well as in the insert type, present the major problem of maintaining adequate bolt tension.

Pull-In or Wear of The Crossing Assembly

Values of pull-in or wear of the crossing assembly have been included in the tables covering the bolt tension loss cycles at the three locations. These values were concurrent with the drop in tension of the respective bolts. In other words, the amount of pull-in for each test cycle was the difference in the out-to-out readings taken for the initial and remaining values of measured bolt tension. During the early stage of the field tests, it was developed, in many instances, that the relation between the pull-in and final tension of the individual bolts, with respect to the release curve for the spring washer and bolt deformation, was not good. After measurement of the dynamic impacts in the main bolts of the westward crossing at Warsaw, it was determined, particularly for the No. 1 position bolts with relatively large shock loads, that the bolt tension was also dissipated by the shock loads causing the washers to imbed into the nuts and corner braces. For instance, if a bolt is torqued to 40,000 lb static tension, and a shock load is imposed by the traffic for a total tension of 55,000 lb, then the higher tension causes the washers to become imbedded deeper into the nut and corner brace and dissipate some of the initial static tension. Obviously, this effect was not included in the pull-in measurements, which were based on the change in out-to-out dimension of the corner braces or joint bars.

Considering the No. 1 bolts in only the 40,000 lb initial bolt tension cycles for the bolted-rail crossings, the rate of pull-in per month for the single-coil washers was approximately 0.002 in at Warsaw and 0.003 in at the 37th St. location. The higher values at the latter location may have been influenced by these crossings being four years older than the eastward crossing at Warsaw. The corresponding figure for the insert crossings at the 55th St. location was less than the value of 0.002 in for the Warsaw crossing. The larger average values in the solid crossing ranged up to 0.002 in per month. The rate of pull-in for the double-coil Hy-Crome washers at Warsaw was about the same as for the single-coil washers at that location. All of the foregoing values are based on the average length of bolt tension loss cycles of 6 to 7 months. Because of the many variables in traffic conditions as well as maintenance conditions and practices, it is apparent that the frequency of retightening crossing frog bolts to a certain standard will vary widely for the many sets of conditions.

Under the test conditions, it was not possible to determine accurately the relation between the rate of pull-in and the magnitude of the initial bolt tension. There were appreciable variations in the pull-in at the No. 1 bolts in the four corners of the same crossing. However, an analysis of the total wear at the No. 1 bolts of the crossing at Warsaw indicated the same rate per month for the cycles with 25,000, 30,000 and 40,000 lb initial tension. The total wear was determined from the change in the out-to-out dimensions taken before and after a test period when the bolts were set at their initial tension.

MISCELLANEOUS OBSERVATIONS

Broken Washers

All spring washer breakage which occurred in the four-year test of the eastward crossing at Warsaw was noted in Tables 2 to 10, incl. At that location there was no breakage of the following washers: Hubbard experimental, PRR specification, Reliance Heavy-Duty Hy-Crome, and Reliance Frog and Crossing Hy-Crome.

During the 3-year test of two bolted-rail crossings at the 37th St. location, 11 Hubbard experimental and 30 used PRR specification washers were broken. There were no Reliance Frog and Crossing Hy-Crome washers broken.

At the 55th St. location there was no breakage of the new spring washers tested. Three of the used washers, one 1¼-in Standard Hy-Crome, one 1¼-in Hy-Pressure Hy-Crome, and one 1⅜-in Hy-Pressure Hy-Crome were broken during the 5-year test of the three crossings.

Bolt Wrenching and Breakage

In the older crossings at the 37th St. and 55th St. locations, some of the bolts were difficult to tighten to 40,000 lb, because the threads had been battered by the washers when the bolts were loose. In a few instances the bolts could not be wrenched to 40,000 lb tension with 2 men. At the 37th St. location in 1951, when the test crossings were 7 years old, it was necessary to replace 10 bolts (of a total of 96) to facilitate the wrenching. Four 1¼-in bolts were replaced with new ones in the insert crossings at the 55th St. location in 1950. Some of the bolts in the older crossings required three-man wrenching. The foregoing difficulties can be avoided by lubricating the bolt threads with a grease known to have good weather-resisting qualities and by not permitting the nuts to become entirely loose, which will prevent the threads from becoming battered.

There was no breakage of any of the main bolts in the crossings in which bolt tension tests were conducted.

Stretching of Bolts

All of the main crossing and turnout bolts tested had been in service prior to the beginning of the bolt tension tests, and the extensometer readings indicated that none had been permanently elongated during these tests. Because of battered threads, 10 of the 1⅜-in main bolts in the crossings at the 37th St. location were replaced with new ones in 1951. Also, 4 of the 1¼-in No. 2 bolts in the insert crossings at the 55th St. location were renewed in 1950. None of the replacement bolts was found to be permanently elongated in the subsequent tension tests. Dissipation of bolt tension by permanently elongating the high-strength frog bolts is of little consequence.

Nut Back-Off

None of the nuts backed off of bolts that still had some tension left. A few of the nuts backed off in cases where the bolt tension became zero. In some instances, with no tension, the nut had not backed off. In one instance where a locknut without a washer was replaced with an ASA heavy medium-carbon nut on crossing "A" at the 55th St. location, the nut backed off of the bolt completely, but the bolt remained in place. Nut back-off did not dissipate bolt tension, as it occurred only after the bolts were loose. This deduction was based on the fact that nuts had not backed off of bolts with 1000 to 2000 lb tension, and did not always back off the bolts that had no remaining tension.

LABORATORY TESTS OF SIMULATED SHOCK LOADS ON CROSSING FROG BOLT ASSEMBLIES

During this five-year field investigation, careful observations were made of the indentation and abrasion of the nuts and corner braces of the crossings by all types of spring washers. Many specimens of nuts were examined in the laboratory by measuring the depth of the indentation. These measurements partially explained the lower efficiency of the medium and heavy weight single-coil spring washers. It was also determined that washers of the S–300 and D–5 compression types caused less indentation and resultant dissipation of the bolt tension. The imbedding of the double-coil washers was found to be much less than that of the single-coil washers, because of the greater bearing area on the nuts and corner braces. Because of the importance of this phase of the work, it was decided to conduct laboratory imbedding tests on 1⅜-in bolts with the same nuts and corner brace material as encountered in the field. By this means, the imbedding characteristics of the several types of washers could be translated into reactive pressures and efficiency of the spring washers.

Preparation of Bolt Assemblies

All specimens were made to test spring washers for 1⅜-in bolts. All nuts used were of the ASA heavy medium carbon steel, except one bolt was tested with a heat-treated nut and a hardened flat plate washer next to the corner brace block. After freezing a nut on a 1⅜-in heat-treated bolt by wrenching it to the end of the threads, the excess threads were cut off and the top of the assembly was machined so that the compressive load applied to the threaded end of the bolt would be partially carried by the nut to avoid any movement of the nut with respect to the bolt. The bolt was then cut to a length of 4⅜ in, the excess shank being used to guide the bolt in a dummy block below the corner brace. The Ramapo Ajax Division, American Brake Shoe Company, furnished three short pieces of corner brace material. The chemical analysis indicated the steel had 0.25 percent carbon and 0.55 percent manganese. The corner brace bars had a Brinell hardness of 136. The medium carbon nuts used had an average Brinell hardness reading of 138. The heat-treated medium-carbon nut had a hardness reading of 229, toward the lower end of the range. The hardened flat plate washers averaged 400 Brinell hardness. The corner brace bars were machined on top to provide a good surface for the spring washers. Likewise, the working face of the nut was machined.

Test Procedure

These tests were conducted in a Baldwin–Southwark hydraulic compression–tension testing machine. Each of the single-coil and S–300 spring washers was preloaded to 60,000 lb to avoid any perceptible permanent set during the tests. It was necessary to preload the double-coil washers with 75,000 lb to prevent permanent set during the test. The preloading was performed on special hardened blocks, the same as used for testing washers for their reactive properties. This test simulated a 40,000-lb static bolt tension and shock loads of 20,000 lb, or a total cyclic operating load of 60,000 lb. Each specimen was tested in exactly the same manner when assembled with a bolt and corner brace.

After preloading the washers, each was placed in a separate assembly of bolt, nut and corner brace block. The testing machine was set up for taking reactive pressure curves with an Ames dial indicator for measurement of the movement of the top platen. The specimen washer was first loaded to 40,000 lb, taking dial readings at 100 lb and 40,000 lb. A release curve to 0.060 in was then taken, which was plotted as curve 2 in Fig. 16. Then the load was increased to 60,000 lb and released to 40,000 lb five times. On the sixth release of the load from 60,000 lb, the platen was released to the same dial reading as was obtained for the first load of 40,000 lb. The load measured was used for plotting curve 3 at zero release in Fig. 16. From that load, a release curve was taken to 0.060 in. Release curve 1 in the figure was taken on the hardened blocks prior to the shock load tests.

DISCUSSION OF TEST RESULTS

For convenient comparison of these tests with nine conditions, all of the graphs of the release curves have been included in Fig. 16. The loss in reactive pressure of the washers between curves 1 and 2 represents the effect of the relatively soft bearing surfaces prevalent in crossing frog construction. The spread between curves 2 and 3 is the effect of the six 20,000-lb shock loads. In practically all of the tests the dial readings remained constant for the 60,000-lb loads after the first application. Therefore in track, only one large shock load is all that is necessary to dissipate tension by imbedding due to shock loads. Because of the small scale used in Fig. 16; pertinent values of the reactive pressures have been shown as items a and b at a release of 0.030 in, which are defined in the legend.

It will be observed in the left portion of the first 6 graphs (except No. 4), Fig. 16, that the washers lost more of their effectiveness before application of the shock loads (difference between curves 1 and 2). In graph 4 the Heavy-Duty Hy-Crome washer lost most of its effectiveness after the shock loads. This finding contributed much to the explanation of the low effectiveness developed in the field by the last-mentioned washer when used without hardened parts. By comparing graphs 2 and 5, the advantage of the hardened parts is demonstrated. However, there was little difference in the release curves after the shock loads at the release point of 0.030 in. In the field tests, the hardened parts improved the efficiency of the medium reaction washers but not in the case of the Heavy-Duty Hy-Crome washer with a high reaction.

The drops in the release curves of the double-coil washers in graphs 7, 8 and 9, before and after the application of the shock loads, were about equal.

The improved lot of S–300 plate washers gave good performance in track. Graph 6 (Fig. 16) indicates that the shock loads had little effect on the efficiency of this washer. Likewise, the shock loads caused little drop in the release curve for the washer with hardened parts in graph 5.

RECOMMENDATIONS

Specifications for Spring Washers

It is obvious from the test measurements that maintenance of a high bolt tension will be beneficial in keeping the various parts clamped tightly together so that the amount of relative movement between the parts and resultant wear will be minimized. In addition, a high bolt tension is beneficial in providing some stiffness of the crossing frog to resist deflection under wheel loads and thereby aid the supporting ties in maintaining a good surface over the crossing. The function of the spring washer is to aid in maintaining this bolt tension on a practical basis, so the labor cost for retightening, as required, will be minimized.

As previously discussed, 40,000 lb initial tension is about the practical limit of hand wrenching with the average condition of bolts. Therefore, it is recommended that the applied load in the specification test shall be 40,000 lb.

Because the No. 1 bolts in a bolted-rail crossing have the largest rate of bolt tension dissipation, emphasis should be placed on the requirements for those bolts. The value of the spring washer in maintaining bolt tension depends upon its ability to maintain a reactive force as wear occurs and the faces, which the bolt head and nut contact, come closer together, which is referred to in the report as "pull-in". In the test measurements which extended over a period of several years, it was found that the average amount of pull-in for the No. 1 bolts at the Warsaw crossing approximated 0.002 in per month; in the bolted-rail crossings at the 37th St. location, 0.003 in per month; in the manganese insert crossings at the 55th St. location, less than 0.002 in per month; in the solid manganese crossing at the latter location, up to 0.002 in per month. This would indicate that for the various types of crossings over a period of 1 year the pull-in would range from 0.024 to 0.036 in. Inasmuch as a pull-in value of 0.030 in has been used in specification requirements for spring washers for track joints, and since this pull-in value agrees reasonably well with the pull-in measurements on the crossings, it would seem desirable to use this same value of 0.030 in. in establishing the release distance for reactive pressure requirements of spring washers for crossing frogs.

With reference to the minimum bolt tension that is permissible before bolts should be retightened in order to maintain efficient functioning of the crossing frog assemblies, it is difficult to establish this value on any precise and definite basis. It is apparent, as previously stated, that the tighter the bolts the better. However, it does appear from the test measurements that the crossing frog functioned reasonably well and the rate of wear was not appreciably increased as long as the bolt tension was maintained above 10,000 lb. Accordingly, it is recommended that this value be used as the minimum bolt tension at the release point in the specification requirement.

In view of the fact that the investigation has shown the very great importance on the reactive characteristics of the imbedding action of spring washers into the relatively soft surfaces of the crossing brace and nuts, it seems necessary that this be included in the method of making the reaction test on the spring washers. Accordingly, it is recommended that the reaction test on the washers be made with the washer placed between steel plates in the testing machine, both above and below the washer, and that these steel plates shall have a Brinell hardness not to exceed 150, which is in conformity with th hardness of the crossing brace and medium carbon nuts.

Also, since the measurements of impacts on the bolts under traffic at Warsaw showed that there was an increase in the bolt tension due to the flexural action of the crossing frog (termed shock load in this report), and since this will have an important influence on the reactive characteristics of the washer due to the imbedding action, it is necessary that provision for this be included in the reaction test. Study of the bolt tension measurements indicates that an increase in the applied load of 40,000 lb up to 60,000 lb will be adequate for maximum shock loads.

The recommendation, therefore, for the reaction test for spring washers for crossing frogs is as follows:

(a) Place the test washer in the testing machine between two steel plates not less than ½ in thick, having smoothly ground surfaces and a Brinell hardness not to exceed 150.

(b) Apply an initial load of 40,000 lb and record the dial reading for the position of the platens of the machine.

(c) Increase the test load to 60,000 lb.

(d) Release the load until the distance between platens is 0.030 in greater than that recorded in (b) above.

(e) The amount of load remaining in (d) shall be not less than 10,000 lb.

Observation of Fig. 16 shows that only one of the spring washers tested will meet this suggested specification requirement. That is the Reliance Double-Coil Hy-Crome spring washer shown in graph 7. However, it is believed that by giving consideration to minimizing the loss due to imbedding of the contact surfaces and using a sufficient cross sectional area, any manufacturer that so desires can meet these requirements.

Design of Spring Washers

It has been shown, both in the field tests and the laboratory tests of shock loads, that the imbedding of the washers in the bearing surfaces caused by the larger shock loads resulted in major losses in tension. It is possible that changes in the shape of coil washers may reduce the loss in tension attributed to the shock loads. Consideration should be given in the design of helical spring washers to provide more bearing area against the nut and corner brace when the washer goes solid and when it has opened slightly. Most of the spring washers are thicker at the inner periphery than at the outer one. The laboratory imbedding tests showed a concentration of the indentation on relatively small areas near the outer periphery of the bolt. A washer of uniform thickness should increase the width of the bearing areas and aid in reducing the depth of the indentation and abrasion, as well as the attendant dissipation of tension. Some washers are made of a cross section having sharp corners along the outer edges. When slightly open, in some instances these washers have only a line bearing on the edges diametrically opposite to the ends of the single coil. It is believed that the corners should have a little longer radius. Also, imbedding is concentrated at the heel of the ground deflection, or the chamfer at the ends of the washer, on a small area close to the inner periphery of the helical washers. Any improvement in spring washer designs that will enlarge the contact area and reduce the dissipation of bolt tension chargeable to the major shock loads will promote economy in maintaining bolt tension and simplify the problem of complying with the new specification.

Conclusions

The major loss of tension in frog bolts can be attributed primarily to wear of the crossing assembly, imbedding and abrasion from the shock loads, and possibly some corrosion. Stretching of the bolts and nut back-off were found to have a negligible effect on bolt tension dissipation.

The double-coil spring washers tested held the bolt tension above 20,000 lb twice as long as the single-coil washers.

The use of hardened nuts and hardened flat plate washers next to the corner braces increased the efficiency of the medium weight single-coil washers, but were of little benefit when used with the Heavy-Duty Hy-Crome washers.

The maintenance of bolt tension in the No. 15 railbound turnout frog was a minor problem as compared with the crossing frog bolts.

All types of the spring washers tested with the conventional construction lost some of their effectiveness because of the relatively soft bearing surfaces next to the washers.

Locknuts were not beneficial in the retention of bolt tension. No locknuts backed off of the bolts during these tests.

Nuts having the standard National Coarse thread did not back off as long as the bolt had some tension, and many of the nuts on bolts with zero tension did not back off.

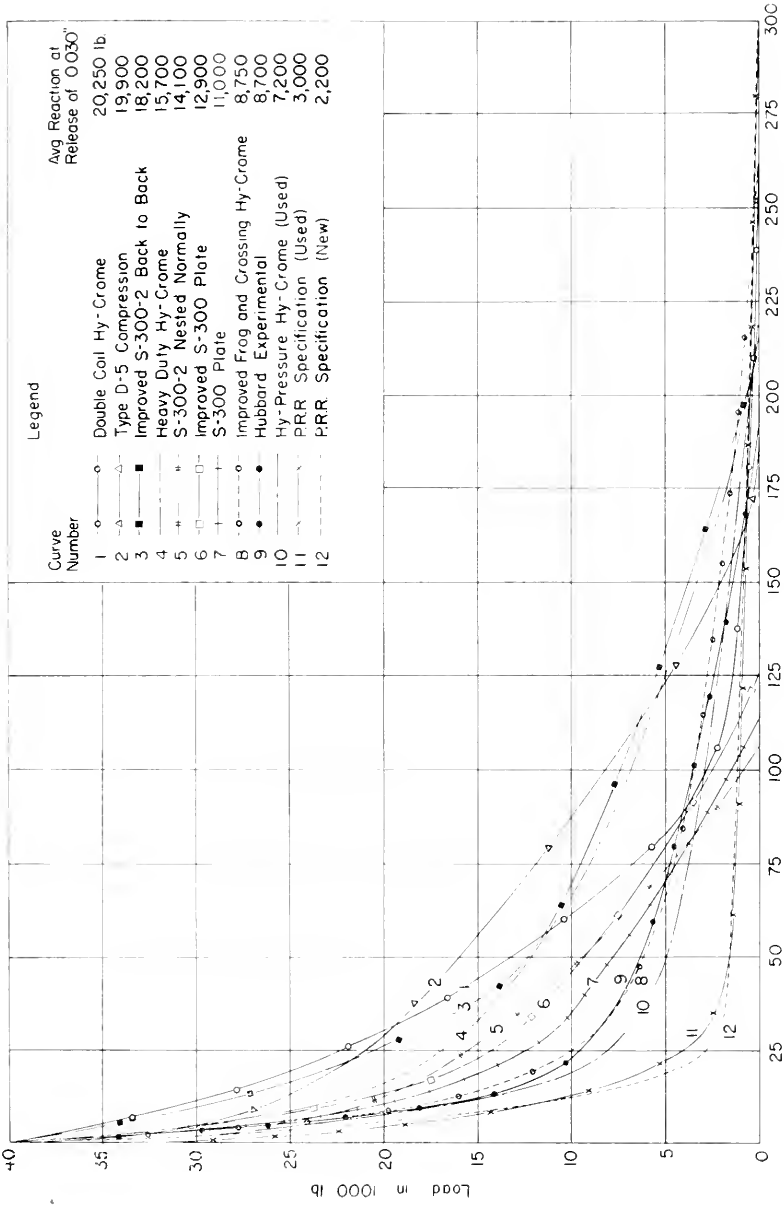


Fig 1 Mean Reactive Spring Pressure Curves of Spring Washers for 1-3/8" Frag Bolts (40,000 lb load)

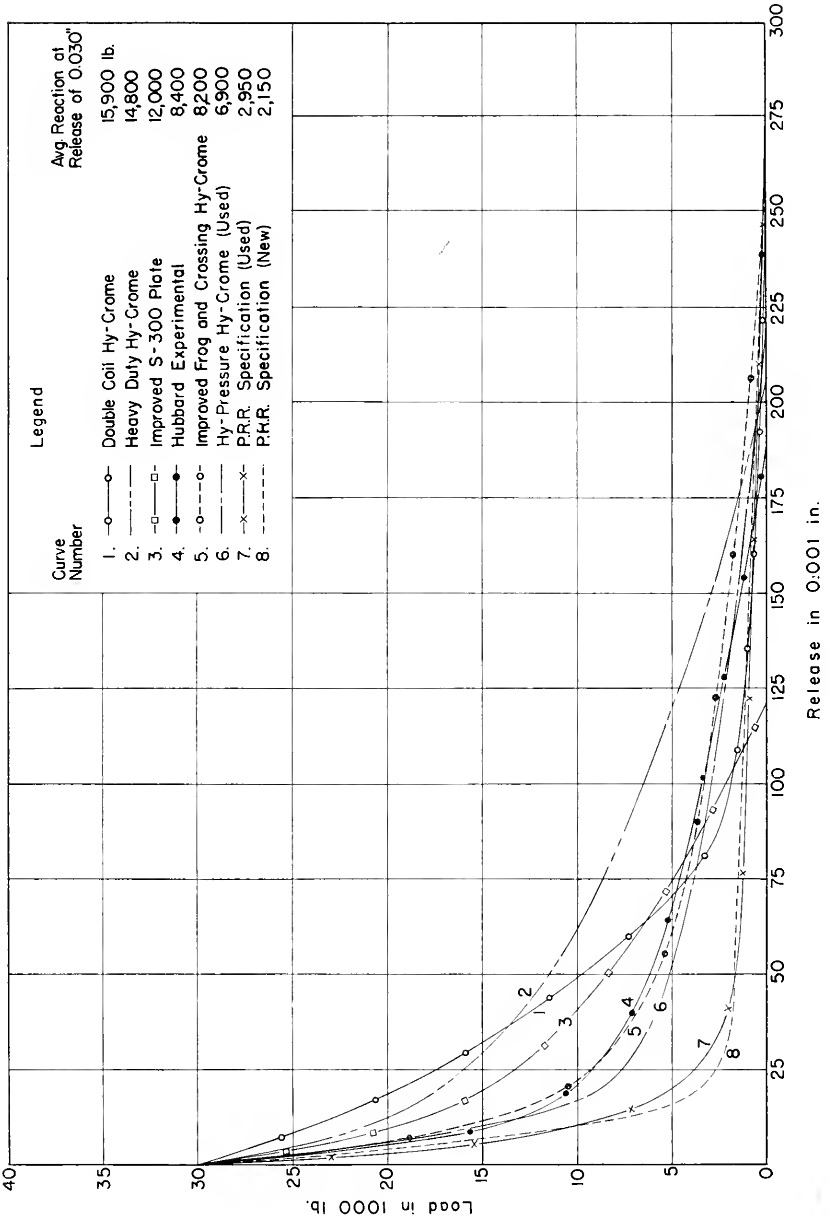


Fig. 2 Mean Reactive Spring Pressure Curves of Spring Washers for 1-3/8" Frog Bolts. (30,000 lb. load)

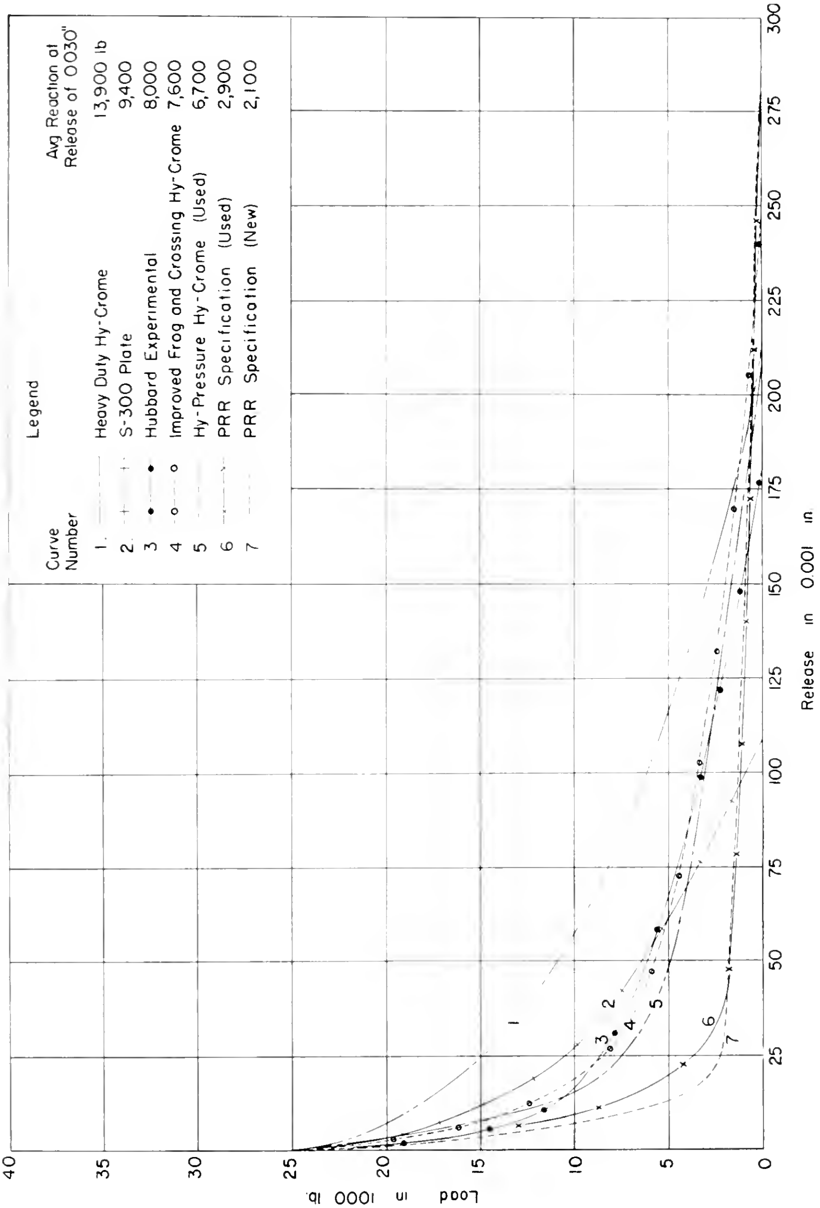


Fig 3 Mean Reactive Spring Pressure Curves of Spring Washers for 1-3/8" Frag Bolts (25,000 lb load)

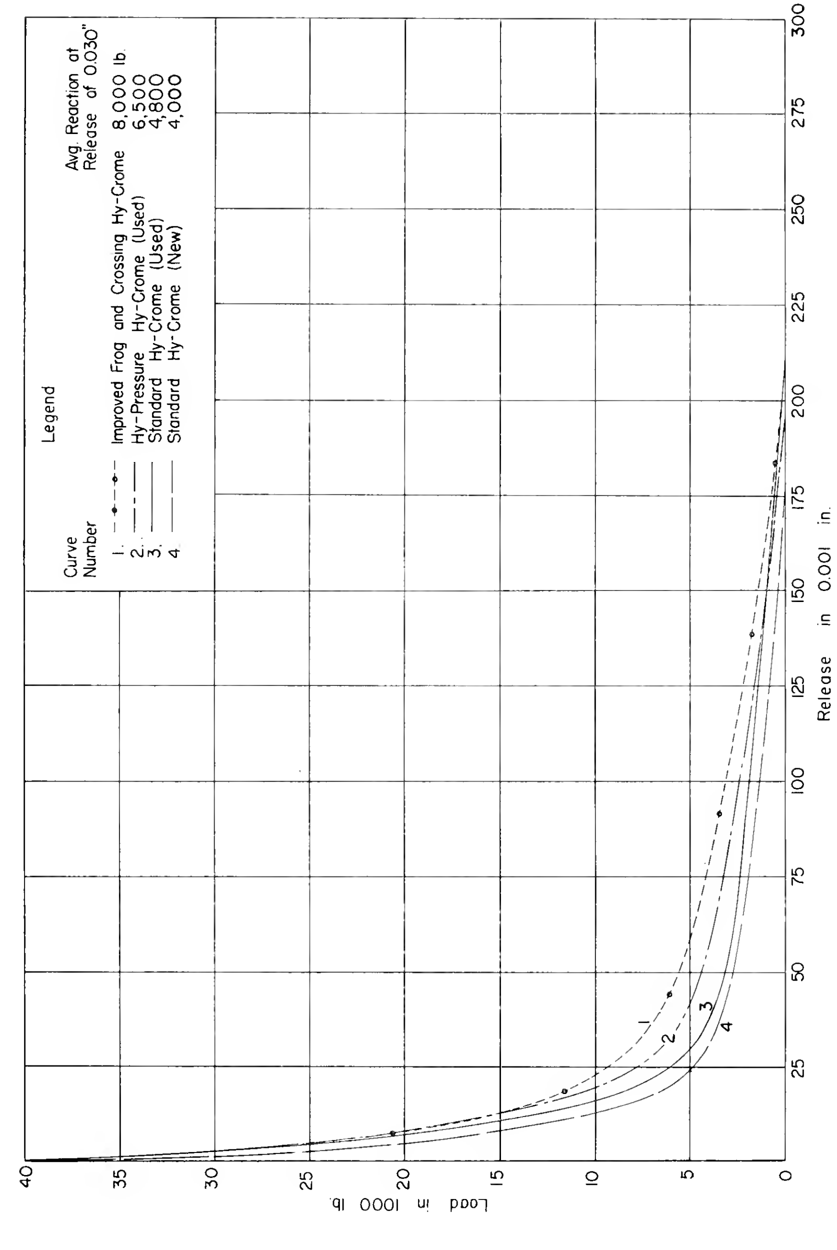


Fig. 4. Mean Reactive Spring Pressure Curves of Spring Washers for 1-1/4" Frog Bolts (40,000 lb. load)

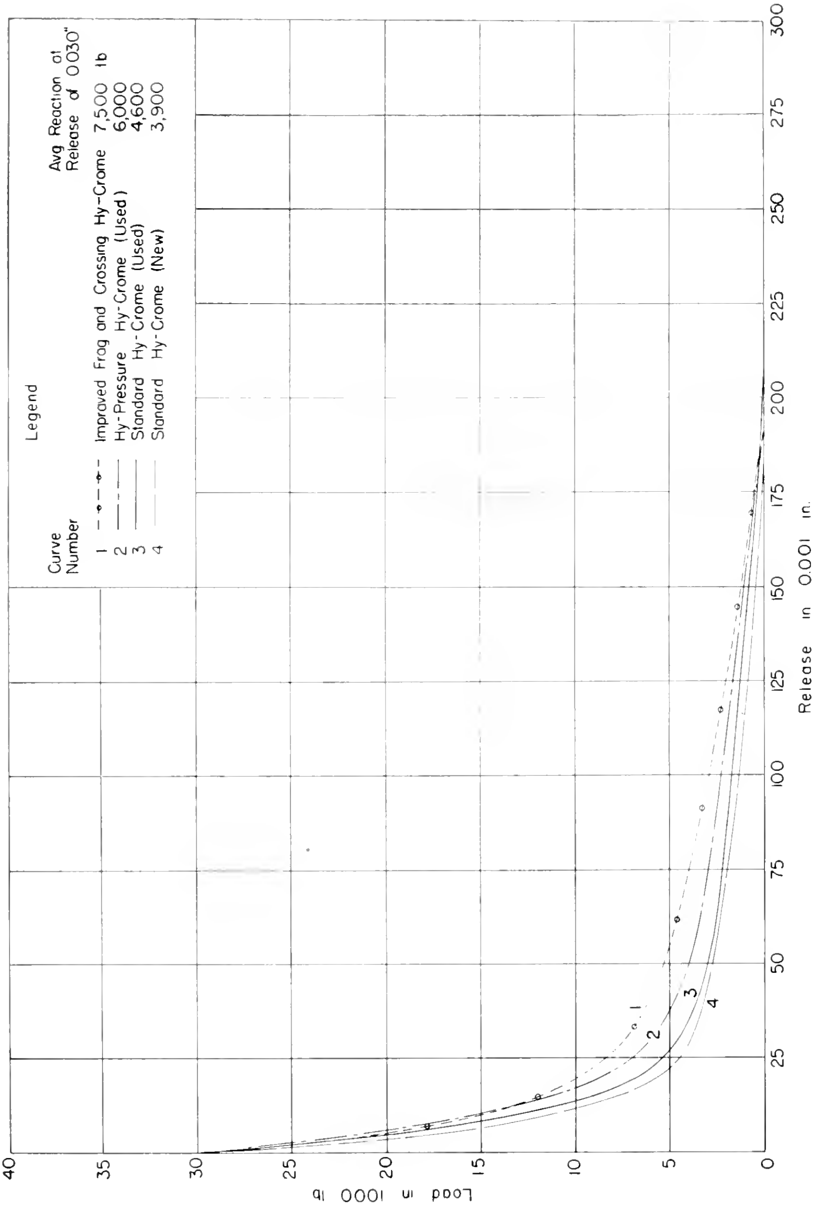


Fig 5. Mean Reactive Spring Pressure Curves of Spring Washers for 1-1/4" Frog Bolts (30,000 lb load)

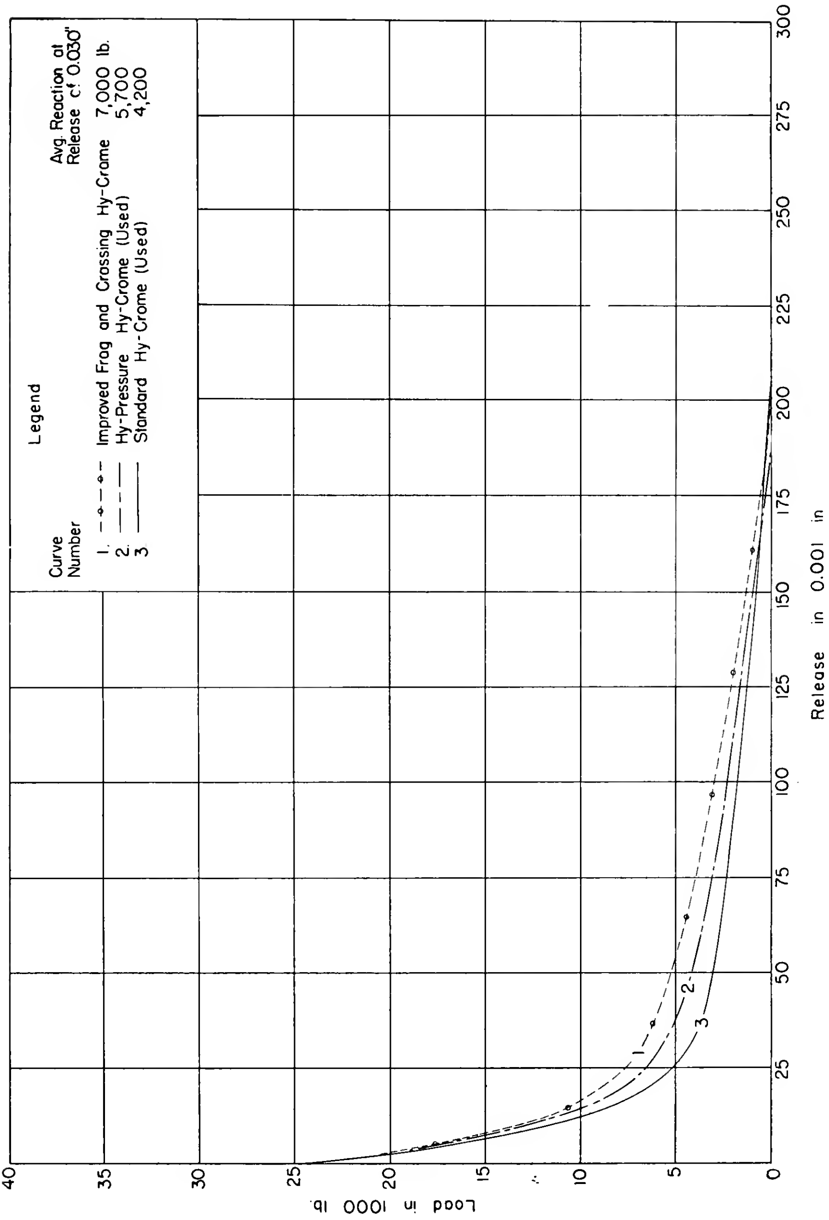


Fig. 6. Mean Reactive · Spring Pressure Curves of Spring Washers for 1-1/4" Frog Bolts. (25,000 lb. load)

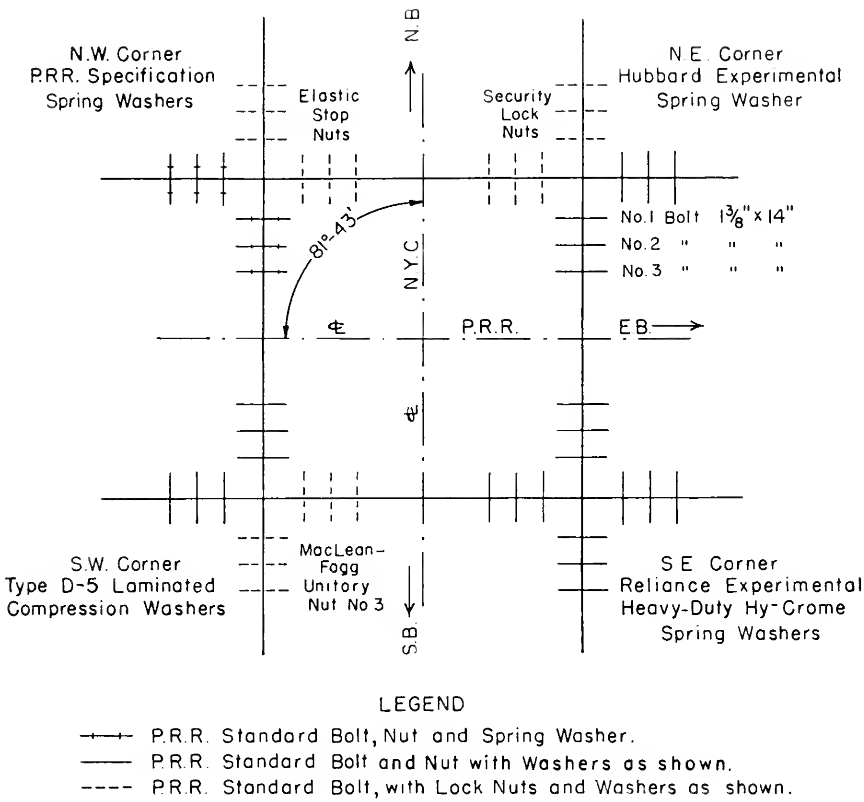


Fig. 7. Plan of P.R.R.—N.Y.C. Crossing at Warsaw, Indiana, Showing Position and Description of Bolts, Washers and Lock Nuts for the Second Test Cycle.

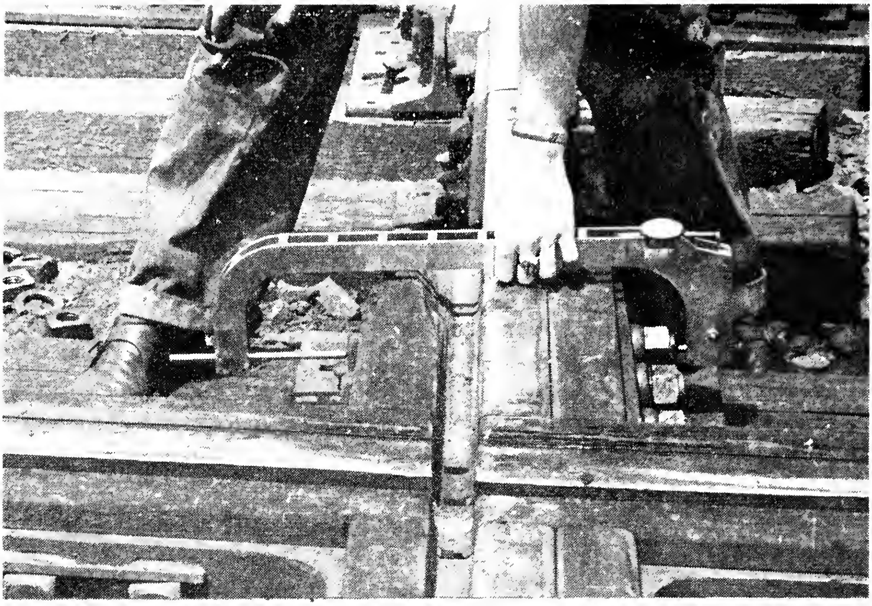


Fig. 8. Extensometer Used for Determining The Loss in Frog Bolt Tension

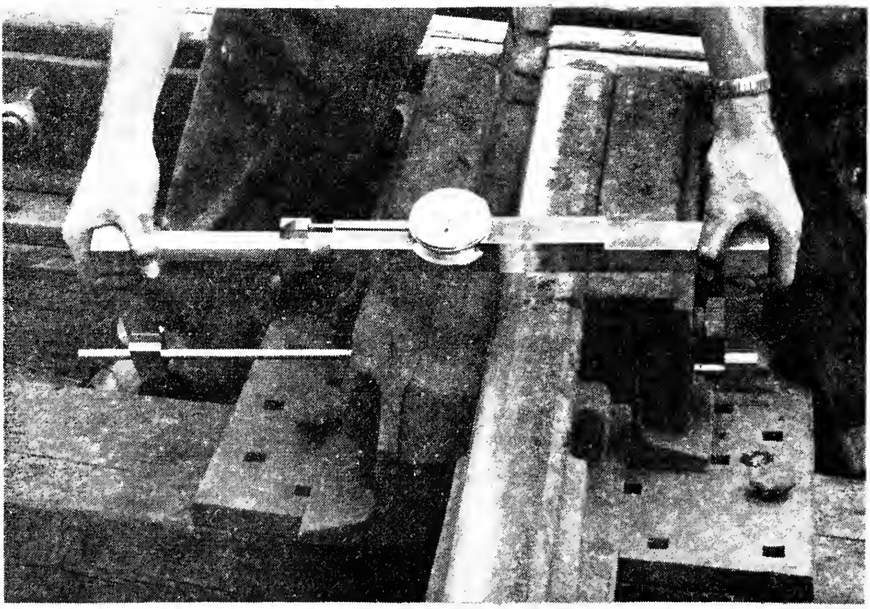
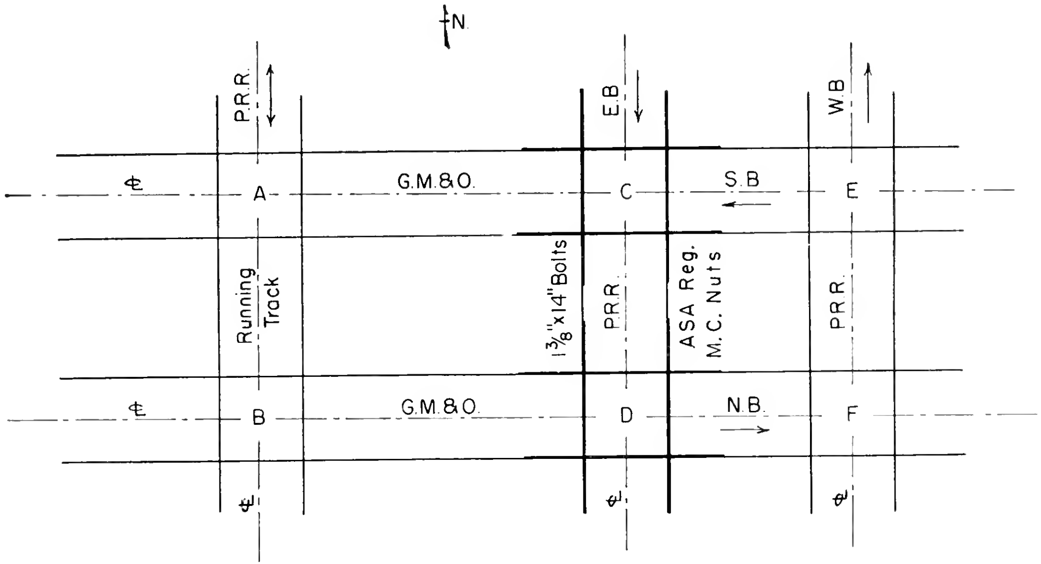
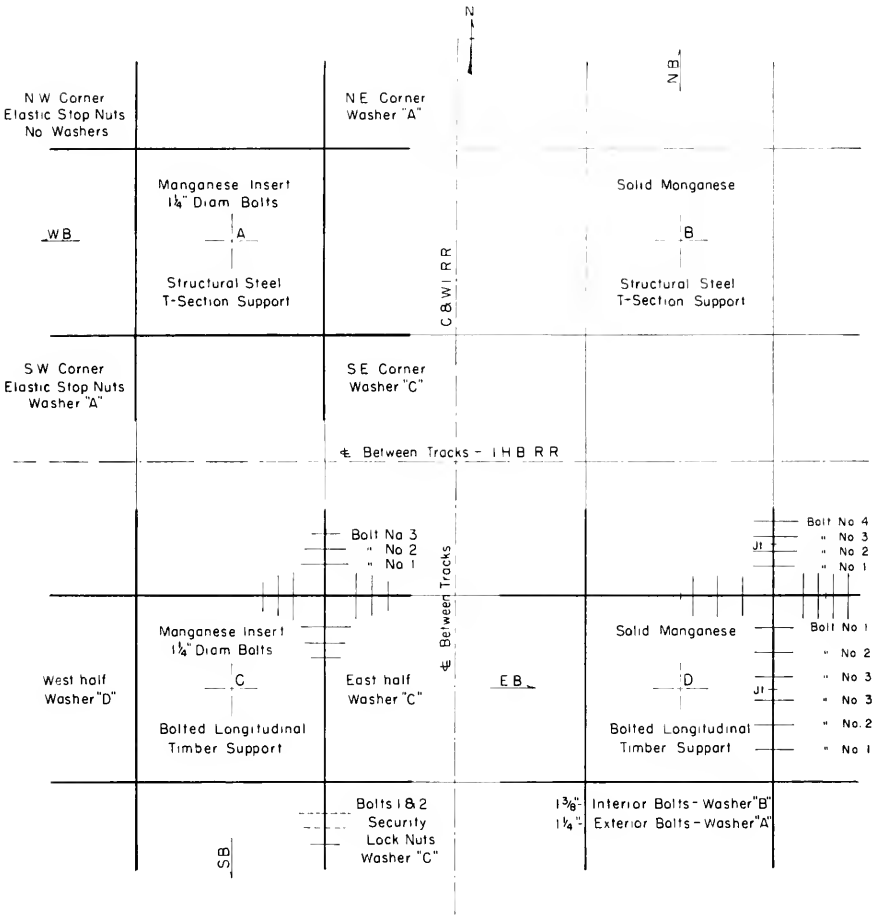


Fig. 9. Out-to-Out Gage for Determining The Pull-In or Wear of Frog Assemblies



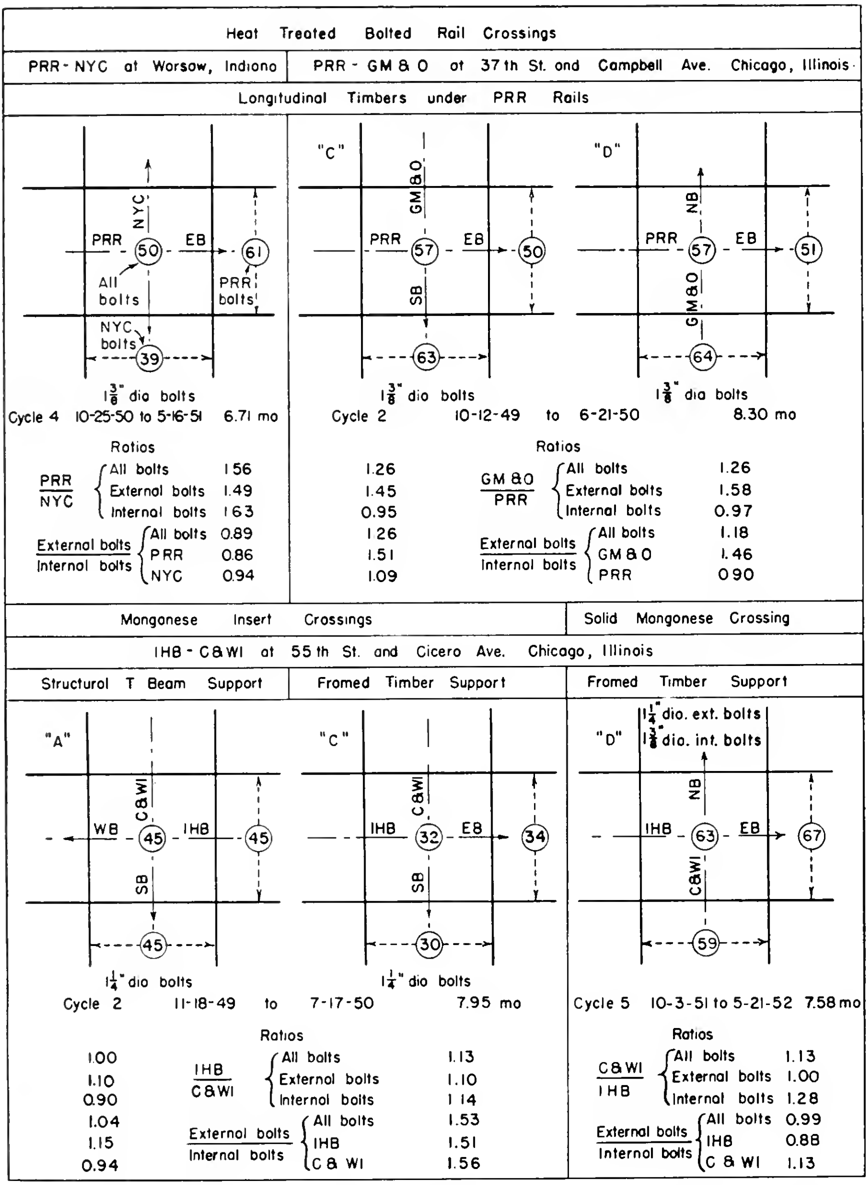
Note: Test Crossings are Crossings "C" and "D".
West Half of Both Test Crossings Contains Used P.R.R. Specification Spring Washers.
East Half of Crossing "C" Contains the Hubbard Experimental Spring Washers.
East Half of Crossing "D" Contains the Reliance Improved Frog and Crossing Hy-Crome Spring Washers.

Fig 10. Plan of P.R.R.—G.M.&O. Crossings at 37th. St. and Campbell Ave., Chicago, Illinois, Showing Location of Test Crossings, Direction of Traffic and Construction for All Test Cycles



Note Washer "A" Reliance Hy-Pressure Hy-Crome Spring Washer
Washer "B" Reliance " " " " "
Washer "C" Reliance Standard Hy-Crome Spring Washer
Washer "D" Reliance Imp F & C Hy-Crome Spring Washer
All nuts are ASA Hvy. M.C. plus $\frac{1}{4}$ in thicker

Fig 11. Plan of IHB - C & W I RR Crossings near 55th St and Cicero Ave, Chicago, Ill, showing the location of bolts, washers and lock nuts, type of crossing and support, and direction of traffic for cycles 1 and 2



Figures in circles indicate percentage loss in tension from 40,000 lb initial tension.

Fig. 12. Typical Patterns and Ratios of Percentage Loss in Bolt Tension for Three Types of Crossings.

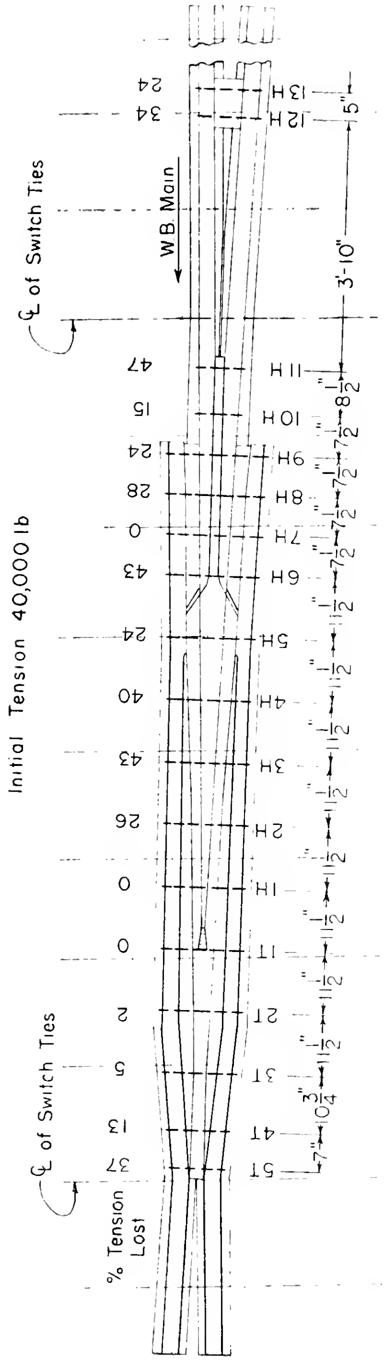


Fig 13.—Loss in Tension in the 1 3/8-in dia Bolts of The No. 15-25-ft-140 PS Railbound Manganese Turnout Frog at Warsaw, Ind. (First cycle, May 3, 1950 to Aug. 15, 1951 - 1.28 yr, PRR Specification Spring Washers)

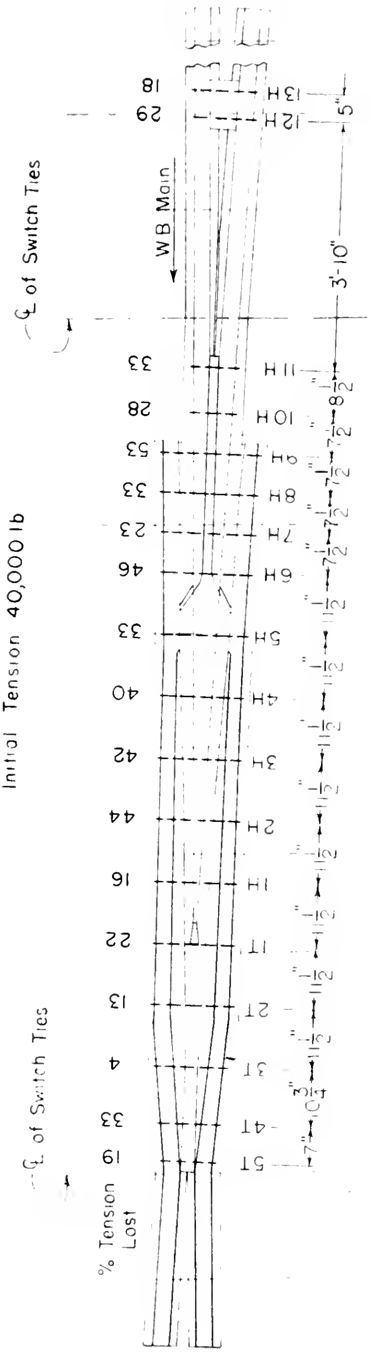


Fig 14. — Loss in Tension in the 1 3/8-in dia Bolts of The No.15-25-ft-140 P S Railbound Manganese Turnout Frog at Warsaw, Ind. (Second cycle, Aug 15, 1951 to Aug. 14, 1952 – 1.00 yr, Frog and Crossing Hy-Crome Spring Washers)

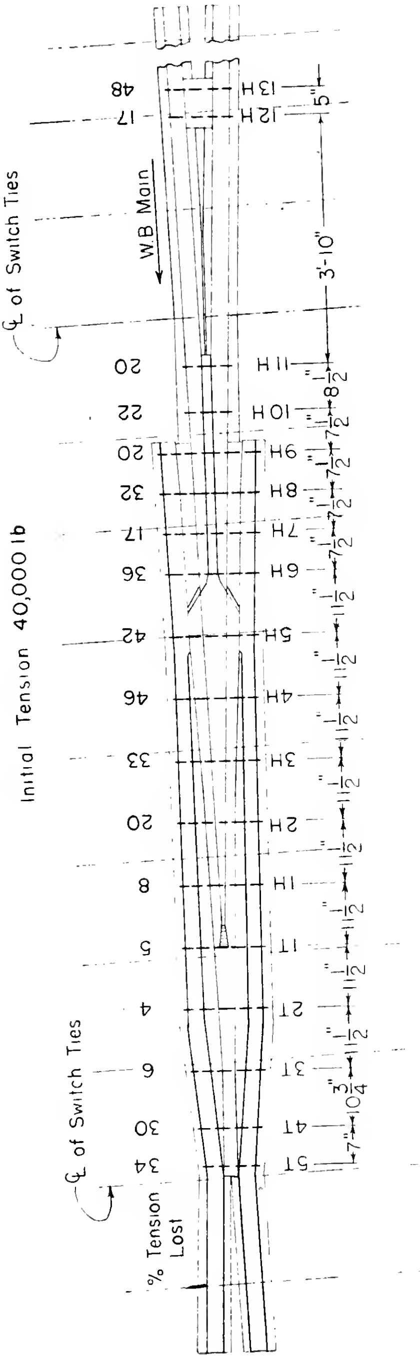


Fig 15.—Loss in Tension in the 1 3/8-in dia Bolts of The No.15-25-ft-140 P S Railbound Manganese Turnout Frog at Warsaw, Ind.
(Third cycle, Aug. 14, 1952 to July 7, 1953—0.90 yr, Frog and Crossing Hy-Crome Spring Washers)

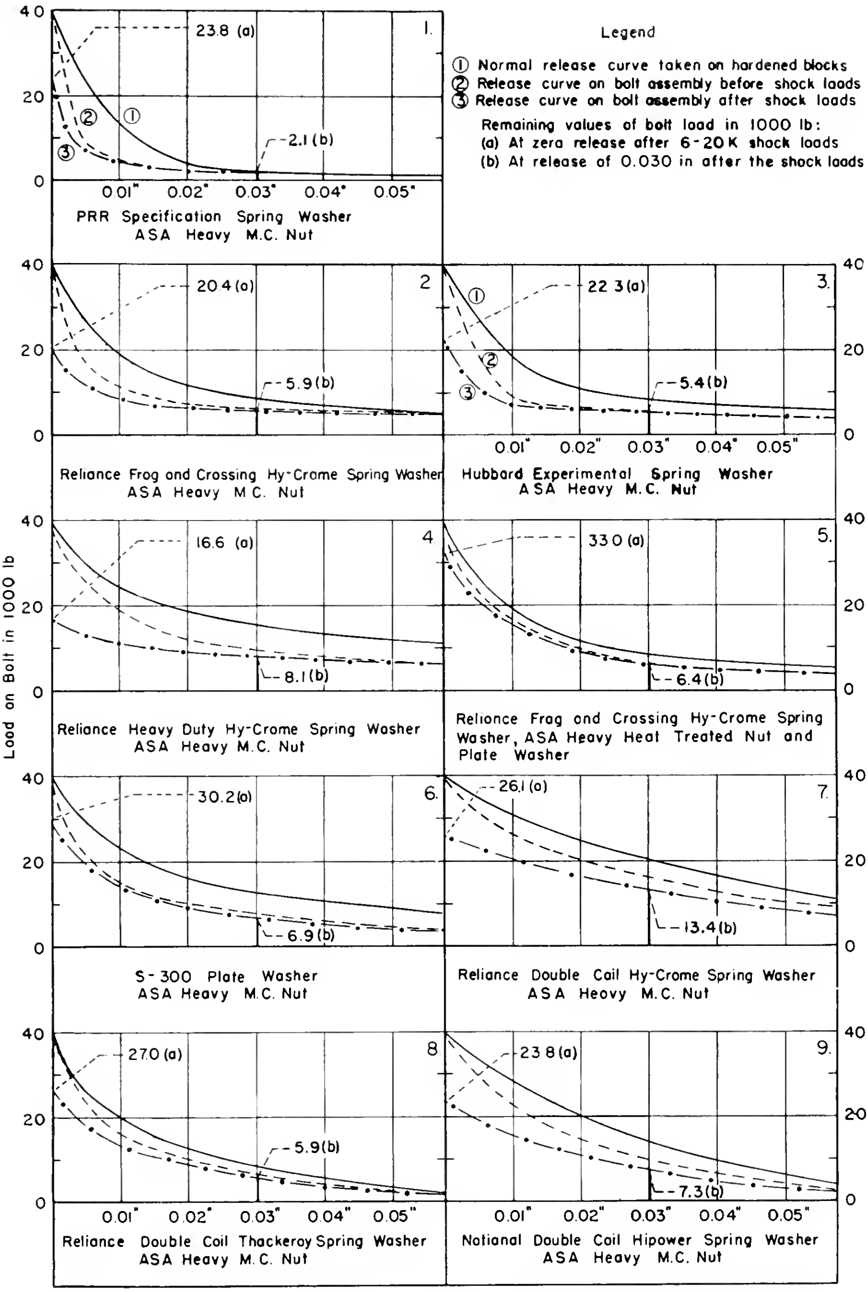


Fig. 16. Spring Washer Release Curves for $1\frac{3}{8}$-in Bolts Showing the Effect of Imbedding into the Crossing Frog Nuts and Corner Braces (Initial Bolt Load 40,000 lb and Six 20,000 lb Shock Loads)

Table 1. Summary of Several Physical Characteristics of Spring Washers for Frog Bolts

Designation of Spring Washer	Release from 40,000 lb				Release from 30,000 lb				Release from 25,000 lb				Nom. Dimensions of Cross Sections		Approximate Weight per 1000 pcs. (lb)
	Curve No.	No. of Washers Tested	(a) Average Reaction at 0.030"	(b) Total Deflection (in)	Curve No.	No. of Washers Tested	(c) Average Reaction at 0.030"	(b) Total Deflection (in)	Curve No.	No. of Washers Tested	(c) Average Reaction at 0.030"	(b) Total Deflection (in)	Width (in)	Thickness (in)	
For 1 3/8" Diameter Bolts															
Curve Reference	Fig. 1				Fig. 2				Fig. 3						
Double Coil Hy-Crome	1	4	20,250	0.26	1	4	15,900	0.25					3/4	13/32	1040
Type D-5 Compression	2	2	19,900	0.18									3 x 3	5/8(5 Ply)	1800
Improved S-300 - 2 Back to Back	3	1 Pr.	18,200	0.21											
Heavy Duty Hy-Crome	4	4	15,700	0.22	2	*	14,800	0.21	1	4	13,900	0.21	3/4	3/4	1000
S-300 - 2 Nested Normally	5	1 Pr.	14,100	0.11											
Improved S-300 Plate	6	4	12,900	0.13	3	*	12,000	0.12					3 x 3	19/64	630
S-300 Plate	7	4	11,000	0.12					2	1	9,400	0.11	3 x 3	19/64	630
Improved Frog and Crossing Hy-Crome	8	4	8,750	0.26	5	*	8,200	0.25	4	4	7,600	0.25	7/8	15/32	725
Hubbard Experimental	9	4	8,700	0.19	4	*	8,400	0.18	3	4	8,000	0.18	17/32	21/32	605
Hy-Pressure Hy-Crome (Used)	10	4	7,200	0.22	6	*	6,900	0.22	5	*	6,700	0.21	9/16	1/2	435
P.R.R. Specification (Used)	11	4	3,000	0.29	7	*	2,950	0.28	6	*	2,900	0.28	1/2	3/8	290
P.R.R. Specification (New)	12	4	2,200	0.30	8	*	2,150	0.28	7	4	2,100	0.28	1/2	3/8	290
For 1 1/4" Diameter Bolts															
Curve Reference	Fig. 4				Fig. 5				Fig. 6						
Improved Frog and Crossing Hy-Crome	1	4	8,000	0.22	1	*	7,500	0.20	1	4	7,000	0.20	13/16	7/16	575
Hy-Pressure Hy-Crome (Used)	2	4	6,500	0.19	2	*	6,000	0.19	2	*	5,700	0.18	17/32	15/32	361
Standard Hy-Crome (Used)	3	4	4,800	0.21	3	*	4,600	0.20	3	*	4,200	0.20	1/2	7/16	295
Standard Hy-Crome (New)	4	4	4,000	0.18	4	4	3,900	0.18					1/2	7/16	295

(a) Average reactive spring pressure at fourth release from 40,000 lb.

(b) Deflections measured between indicated load and 100 lb.

(c) Average reactive spring pressure at first release from indicated load after four compressions to 40,000 lb.

* Data developed from 40,000 lb release curve.

TABLE 2. SUMMARY OF THE FIRST CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R.R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Location and Name of Spring Washers	Washer Curve Reference		*Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost			20 K	10 K	
N.W. Corner PRR Specification Spring Washers	1	12	1	42.5	18.0	24.5	58	0.013	2	0	ASA Heavy L.C. Elastic Stop Nuts on North & East Bolts. ASA Regular M.C. Nuts on South & West Bolts
	"	"	2	41.0	21.9	19.1	47	0.008	2	1	
	"	"	3	40.4	26.4	14.0	35	0.007	2	0	
			Avg.	41.3	22.1	19.2	46	0.009	6	1	
N.E. Corner Hubbard Experimental Spring Washers	1	9	1	39.9	17.9	22.0	55	0.023	3	0	ASA Regular Hex. L.C. Security Locknuts on North & West Bolts. ASA Regular M.C. Nuts on South & East Bolts
	"	"	2	38.5	21.9	16.6	43	0.016	1	0	
	"	"	3	40.5	27.6	12.9	32	0.012	1	0	
			Avg.	39.6	22.4	17.2	43	0.017	5	0	
S.E. Corner Used PRR Spec. Spring Washers	1	11	1	39.6	18.5	21.1	53	0.012	3	1	ASA Regular M.C. Nuts
	"	"	2	41.1	26.6	14.5	35	0.009	1	0	
	"	"	3	40.2	15.8	24.4	61	0.009	3	1	
			Avg.	40.3	20.3	20.0	50	0.010	7	2	
S.W. Corner Type D-5 Compression Washers	1	2	1	41.3	23.1	18.2	44	0.022	1	0	ASA Regular L.C. MacLean-Fogg Unitary No. 3 Locknuts on South & East Bolts. ASA Regular M.C. Nuts on North & West Bolts
	"	"	2	40.8	27.2	13.6	33	0.018	0	0	
	"	"	3	38.7	27.3	11.4	30	0.013	0	0	
			Avg.	40.3	25.9	14.4	36	0.018	1	0	

*Each corner of the crossing has twelve 1 3/8-in x 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

These results cover the period from July 12, 1949 to November 9, 1949.

TABLE 3. SUMMARY OF THE SECOND CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R.R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig. No.	Cv. No.		Initial	Final	Lost			20 K	10 K	
N. W. Corner	1	12	1	40.8	10.5	30.3	74	0.011	4	2	ASA Heavy L.C. Elastic Stop Nuts on North & East Bolts. ASA Regular M.C. Nuts on South & West Bolts
PRR Specification	"	"	2	40.3	17.3	23.0	57	0.010	2	2	
Spring Washers	"	"	3	40.3	18.9	21.4	53	0.011	2	1	
			Avg.	40.5	15.5	25.0	62	0.011	8	5	
N. E. Corner	1	9	1	39.1	14.2	24.9	64	0.019	4	0	ASA Regular Hex. L.C. Security Locknuts on North & West Bolts. ASA Regular M.C. Nuts on South & East Bolts
Hubbard Experimental	"	"	2	39.1	18.9	20.2	52	0.015	3	0	
Spring Washers	"	"	3	38.5	24.9	13.6	35	0.009	1	0	
			Avg.	38.9	19.3	19.6	50	0.014	8	0	
S. E. Corner	1	4	1	39.2	13.3	25.9	66	0.015	3	1	ASA Regular M. C. Nuts
Reliance Heavy-Duty	"	"	2	39.4	19.7	19.7	50	0.011	3	0	
Hy-Crome Spring Washers	"	"	3	36.6	22.8	13.8	38	0.006	1	0	
			Avg.	38.4	18.6	19.8	52	0.011	7	1	
S. W. Corner	1	2	(a) 1 (4)	40.8	18.3	22.5	55	0.012	2	0	ASA Regular L.C. MacLean-Fogg Unitary No. 3 Locknuts on South & East Bolts. ASA Regular M.C. Nuts on North & West Bolts
Type D-5 Compression	"	"	2 (2)	40.2	21.5	18.7	47	0.011	1	0	
Washers	"	"	3 (3)	40.3	24.5	15.8	39	0.006	1	0	
			Avg.	40.4	21.4	19.0	47	0.010	4	0	

*Each corner of the crossing has twelve 1 3/8-in x 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

(a) Number of washers having one or more broken layers at end of test cycle.

These results cover the period from November 9, 1949 to June 5, 1950.

TABLE 4. SUMMARY OF THE THIRD CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R.R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig. No.	Cv. No.		Initial	Final	Lost			20 K	10 K	
N. W. Corner	3	7	1	25.4	14.6	10.8	43	0.009	4	1	ASA Regular M. C. Nuts
PRR Specification	"	"	2	25.4	13.5	11.9	47	0.008	3	0	
Spring Washers	"	"	3	25.4	16.4	9.0	35	0.011	2	1	
			Avg.	25.4	14.9	10.5	41	0.009	9	2	
N. E. Corner	3	3	1	25.4	14.6	10.9	43	0.006	4	0	ASA Regular M. C. Nuts
Hubbard Experimental	"	"	2	24.7	15.2	9.5	38	0.007	3	0	
Spring Washers	"	"	3	25.4	17.1	8.3	33	0.006	2	1	
			Avg.	25.1	15.6	9.5	38	0.006	9	1	
S. E. Corner	3	1	1	26.2	16.5	9.7	37	0.005	3	0	ASA Heavy M. C. Nuts
Reliance Heavy-Duty	"	"	2	24.6	17.8	6.8	28	0.004	3	0	
Hy-Crome Spring Washers	"	"	3	24.9	19.6	5.3	21	0.004	2	0	
			Avg.	25.3	17.8	7.5	30	0.004	8	0	
S. W. Corner	3	2	1	25.7	17.8	7.9	31	0.005	3	0	ASA Regular L.C. MacLean-Fogg Unitary No. 3 Locknuts on South & East Bolts. ASA Regular M.C. Nuts on North & West Bolts
S-300 Plate	"	"	2	25.0	18.4	6.6	26	0.003	2	0	
Washers (First lot)	"	"	3	25.9	22.3	3.6	14	0.004	0	0	
			Avg.	25.6	19.6	6.0	23	0.004	5	0	

*Each corner of the crossing has twelve 1 3/8-in x 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

These results cover the period from June 5, 1950 to October 25, 1950.

TABLE 5. SUMMARY OF THE FOURTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R.R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost		20 K	10 K	
N. W. Corner	1	9	1	41.3	16.5	24.8	60	2	0	ASA Heavy M. C. Nuts
Hubbard Experimental	"	"	2	40.3	19.2	21.1	52	2	1	
Spring Washers	"	"	3	40.6	21.5	19.1	47	2	1	
			Avg.	40.7	19.1	21.6	53	6	2	
N. E. Corner	1	12	1	40.3	10.8	29.5	73	4	1	ASA Regular M. C. Nuts
PRR Specification	"	"	2	41.3	21.3	20.0	48	2	0	
Spring Washers	"	"	3	40.5	27.8	12.7	31	1	0	
			Avg.	40.7	20.0	20.7	51	7	1	
S. E. Corner	1	4	1	41.0	14.4	26.6	65	4	0	ASA Heavy M. C. Heat Treated Nuts
Reliance Heavy-Duty	"	"	2	40.4	22.7	17.7	44	1	0	
Hy-Crome Spring Washers	"	"	3	40.4	24.1	16.3	40	1	0	
			Avg.	40.6	20.4	20.2	50	6	0	
S. W. Corner	1	5	1 } b	40.6	20.2	20.4	50	2	0	ASA Regular L.C. MacLean-Fogg Unitary No. 3 Locknuts on South & East Bolts. ASA Regular M. C. Nuts on North & West Bolts
S-300 Plate Washers	1	7	2 } b	41.0	18.6	22.4	55	2	0	
(First Lot) (a)	"	"	3 } b	40.5	27.3	13.2	33	1	0	
			Avg.	40.7	22.0	18.7	46	5	0	

*Each corner of the crossing has 12-1 3/8-in x 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

(a) Two new washers were nested normally on the No. 1 bolts only.
(b) Nine of 16 washers were cracked at the end of service period.

Pull-in measurements were omitted because of inconsistent results.

These results cover the period from October 25, 1950 to May 16, 1951.

TABLE 6. SUMMARY OF THE FIFTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R.R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost			20 K	10 K	
N. W. Corner	2	4	1	30.9	11.1	19.8	64	0.009	4	2	ASA Heavy M. C. Nuts
Hubbard Experimental	"	"	2	31.0	16.1	14.9	48	0.009	3	0	
Spring Washers	"	"	3	30.8	15.8	15.0	49	0.007	4	0	
			Avg.	30.9	14.3	16.6	54	0.008	11	2	
N. E. Corner	2	8	1	30.0	11.0	19.0	63	0.011	3	2	ASA Heavy M. C. Nuts
PRR Specification	"	"	2	31.0	18.1	12.9	42	0.010	2	1	
Spring Washers	"	"	3	30.5	21.5	9.0	30	0.010	1	0	
			Avg.	30.5	16.9	13.6	45	0.010	6	3	
S. E. Corner	2	2	1	30.0	16.2	13.8	46	0.014	3	0	ASA Heavy M. C. Heat Treated Nuts
Reliance Heavy-Duty	"	"	2	30.0	21.3	8.7	29	0.010	1	0	
Hy-Crome Spring Washers	"	"	3	29.4	23.3	6.1	21	0.009	0	0	
			Avg.	29.8	20.3	9.5	32	0.011	4	0	
S. W. Corner	2	3	1(a)	31.1	24.5	6.7	21	0.012	0	0	ASA Heavy M. C. Nuts
S-300 Plate Washers	"	"	2	31.0	23.2	7.8	25	0.011	1	0	
(Improved)	"	"	3	31.3	25.4	5.9	19	0.006	1	0	
			Avg.	31.1	24.4	6.7	22	0.010	2	0	

*Each corner of the crossing has 12-1 3/8-in x 14-in main bolts. The No. 1 bolt position is the nearest to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

(a) Two washers were cracked at the end of service period.

These results cover the period from May 16, 1951 to October 16, 1951.

TABLE 7. SUMMARY OF THE SIXTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R.R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost			20 K	10 K	
N. W. Corner	1	9	1	40.7	22.1	18.6	46	0.010	2	0	ASA Heavy M. C. Heat
Hubbard Experimental	"	"	2	40.2	25.2	15.0	37	0.011	2	0	Treated Nuts and Hardened,
Spring Washers	"	"	3	39.7	26.2	13.5	34	0.008	0	0	Flat Plate Washers
			Avg.	40.2	24.5	15.7	39	0.010	4	0	
N. E. Corner	1	12	1	39.9	14.2	25.7	64	0.003	4	1	ASA Heavy M. C. Nuts
PRR Specification	"	"	2	39.0	17.2	21.8	56	0.003	2	1	
Spring Washers	"	"	3	39.4	22.7	16.7	42	0.002	2	0	
			Avg.	39.4	18.0	21.4	54	0.003	8	2	
S. E. Corner	1	4	1	39.8	17.6	22.2	56	0.011	3	0	ASA Heavy M. C. Heat
Reliance Heavy-Duty	"	"	2	40.4	21.7	18.7	46	0.008	2	0	Treated Nuts and Hardened,
Hy-Crome Spring	"	"	3	39.8	20.7	19.1	48	0.009	1	0	Flat Plate Washers
Washers			Avg.	40.0	20.0	20.0	50	0.009	6	0	
S. W. Corner	1	3	1	39.1	23.0	16.1	41	0.011	1	0	ASA Heavy M. C. Nuts
S-300 Plate Washers	1	6	2	40.0	23.4	16.6	42	0.008	1	0	
(Improved) (a).	"	"	3(b)	40.5	29.7	10.8	27	0.004	0	0	
			Avg.	39.9	25.4	14.5	36	0.008	2	0	

*Each corner of the crossing has 12-1 3/8-in x 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

(a) Two new washers were placed back-to-back on the No. 1 bolts only.
(b) One of 16 washers was cracked at the end of service period.

These results cover the period from October 16, 1951 to May 14, 1952.

TABLE 8. SUMMARY OF THE SEVENTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R.R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.	Position	Initial	Final	Lost			20 K	10 K	
N.W. Corner	2	4	1	29.7	21.0	8.7	29	0.007	1	0	ASA Heavy M.C. Heat
Hubbard Experimental	"	"	2	29.1	22.8	6.3	22	0.006	1	0	Treated Nuts and Hardened,
Spring Washers	"	"	3	30.0	23.2	6.8	23	0.008	1	0	Flat Plate Washers
			Avg.	29.6	22.3	7.3	25	0.007	3	0	
N.E. Corner	2	8	1	30.0	14.2	15.8	53	0.007	4	1	ASA Heavy M.C. Nuts
PRR Specification	"	"	2	29.6	14.9	14.7	50	0.006	3	1	
Spring Washers	"	"	3	29.4	19.2	10.2	35	0.007	2	0	
			Avg.	29.7	16.1	13.6	46	0.007	9	2	
S.E. Corner	2	2	1	29.4	20.2	9.2	31	0.007	2	0	ASA Heavy M.C. Heat
Reliance Heavy-Duty	"	"	2	30.7	24.9	5.8	19	0.007	1	0	Treated Nuts and Hardened,
Hy-Crome Spring Washers	"	"	3	29.5	22.0	7.5	25	0.008	1	0	Flat Plate Washers
			Avg.	29.9	22.4	7.5	25	0.007	4	0	
S.W. Corner	2	1	1	29.7	20.0	9.7	33	0.007	2	0	ASA Heavy M.C. Nuts
Reliance Double Coil	"	"	2	29.8	22.7	7.1	24	0.006	1	0	
Hy-Crome Spring Washers	"	"	3(a)	30.0	24.5	5.5	18	0.005	1	0	
			Avg.	29.8	22.4	7.4	25	0.006	4	0	

*Each corner of the crossing has 12-1 3/8-in by 14-in main bolts. The No. 1 bolt position is the nearest on to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one and the No. 3 the farthest from the intersection.

(a) One washer was broken at the end of service period.

These results cover the period from May 14, 1952 to October 2, 1952.

TABLE 9. SUMMARY OF THE EIGHTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R. R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Part 1. Loss in Tension of the No. 1 Bolts in the N. W., N. E. and S. E. Corners for the Period from October 2, 1952 to January 13, 1953.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Average Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	Remarks
	Fig. No.	Cv. No.		Initial	Final	Lost			
N. W. Corner	1	9	1-N	41.6	31.6	10.0	24	0.002	ASA Heavy M. C. Heat
Hubbard Experimental	"	"	1-S	38.8	29.5	9.3	24	0.007	Treated Nuts and Hardened,
Spring Washers	"	"	1-W	38.1	22.0	16.1	42	0.004	Flat Plate Washers
	"	"	1-E	38.1	17.0	21.1	55	0.007	
			Avg.	39.2	25.0	14.1	36	0.005	
N. E. Corner	1	12	1-N	37.8	21.4	16.4	43	0.002	ASA Heavy M. C. Nuts
PRR Specification	"	"	1-S	38.5	20.6	17.9	47	0.006	
Spring Washers	"	"	1-W	40.6	12.1	28.5	70	0.007	
	"	"	1-E	40.6	13.5	27.1	67	0.007	
			Avg.	39.4	16.9	22.5	57	0.006	
S. E. Corner	1	8	1-N	39.5	24.3	15.2	39	0.004	ASA Heavy M. C. Heat Treated
Reliance Frog and	"	"	1-S	38.8	26.5	12.3	32	0.002	Nuts and Hardened, Flat
Crossing Hy-Crome	"	"	1-W	40.2	19.7	20.5	51	0.006	Plate Washers
Spring Washers	"	"	1-E	40.2	13.4	26.8	67	0.004	
			Avg.	39.7	21.0	18.7	47	0.004	

*Each corner of the crossing has 12-1 3/8-in by 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

TABLE 9. SUMMARY OF THE EIGHTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R. R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Part 2. Loss in Tension of the No. 1 Bolts in the N. W., N. E. and S. E. Corners for the Period from January 13, 1953 to April 17, 1953.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Average Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	Remarks
	Fig. No.	Cv. No.		Initial	Final	Lost			
N. W. Corner Hubbard Experimental Spring Washers	1	9	1-N	39.5	30.9	8.6	22	0.000	ASA Heavy M. C. Heat Treated Nuts and Hardened, Flat Plate Washers
	"	"	1-S	38.8	30.2	8.6	22	0.006	
	"	"	1-W	40.2	31.6	8.6	21	0.003	
	"	"	1-E	40.9	28.9	12.0	29	0.007	
			Avg.	39.8	30.4	9.4	24	0.004	
N. E. Corner PRR Specification Spring Washers	1	12	1-N	41.3	28.6	12.7	31	0.001	ASA Heavy M. C. Nuts
	"	"	1-S	42.0	31.1	10.9	26	0.004	
	"	"	1-W	38.5	20.0	18.5	48	0.004	
	"	"	1-E	39.3	19.2	20.1	51	0.001	
			Avg.	40.3	24.7	15.6	39	0.002	
S. E. Corner Reliance Frog and Crossing Hy-Crome Spring Washers	1	8	1-N	40.9	29.5	11.4	28	0.001	ASA Heavy M. C. Heat Treated Nuts and Hardened, Flat Plate Washers
	"	"	1-S	40.9	37.4	3.5	9	0.006	
	"	"	1-W	40.2	29.5	10.7	27	0.010	
	"	"	1-E	38.1	29.5	8.6	23	0.000	
			Avg.	40.0	31.5	8.6	22	0.004	

*Each corner of the crossing has 12-1 3/8-in by 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

TABLE 9. SUMMARY OF THE EIGHTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R. R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Part 3. Average Loss in Tension of the No. 1 Bolts in the N. W., N. E. and S. E. Corners for the two 3-month periods from October 2, 1952 to January 13, 1953 and from January 13, 1953 to April 17, 1953.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Average Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	Remarks
	Fig. No.	Cv. No.		Initial	Final	Lost			
N. W. Corner	1	9	1-N	40.6	31.2	9.4	23	0.001	ASA Heavy M. C. Heat
Hubbard Experimental	"	"	1-S	38.8	29.8	9.0	23	0.006	Treated Nuts and Hardened,
Spring Washers	"	"	1-W	39.2	26.8	12.4	32	0.004	Flat Plate Washers
	"	"	1-E	39.5	23.0	16.5	42	0.007	
			Avg.	39.5	27.7	11.8	30	0.004	
N. E. Corner	1	12	1-N	39.6	25.0	14.6	37	0.002	ASA Heavy M. C. Nuts
PRR Specification	"	"	1-S	40.2	25.8	14.4	36	0.005	
Spring Washers	"	"	1-W	39.6	16.0	23.6	59	0.006	
	"	"	1-E	40.0	16.4	23.6	59	0.004	
			Avg.	39.8	20.8	19.0	48	0.004	
S. E. Corner	1	8	1-N	40.2	26.9	13.3	33	0.002	ASA Heavy M. C. Heat
Reliance Frog and	"	"	1-S	39.9	32.0	7.9	20	0.004	Treated Nuts and Hardened,
Crossing Hy-Crome	"	"	1-W	40.2	24.6	15.6	39	0.008	Flat Plate Washers
Spring Washers	"	"	1-E	39.2	21.4	17.7	45	0.002	
			Avg.	39.9	26.2	13.6	34	0.004	

*Each corner of the crossing has 12-1 3/8-in by 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

TABLE 9. SUMMARY OF THE EIGHTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R.R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Part 4. Loss in Tension of the No. 2 and 3 Bolts in the N. W., N. E. and S. E. Corners and of the No. 1, 2 and 3 Bolts in the S. W. Corner for the Period from October 2, 1952 to April 17, 1953.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost			20 K	10 K	
N. W. Corner Hubbard Experimental Spring Washers	1	9	2	39.2	28.7	10.5	27	0.008	1	0	ASA Heavy M. C. Heat Treated Nuts and Hardened, Flat Plate Washers
	"	"	3	39.8	31.4	8.4	21	0.007	0	0	
			Avg.	39.5	30.0	9.5	24	0.008	1	0	
N. E. Corner PRR Specification Spring Washers	1	12	2	39.5	14.5	25.0	64	0.008	2	1	ASA Heavy M. C. Nuts
	"	"	3	40.8	25.3	15.5	38	0.008	0	0	
			Avg.	40.2	19.9	20.3	51	0.008	2	1	
S. E. Corner Reliance Frog and Crossing Hy-Crome Spring Washers	1	8	2	40.0	22.5	17.5	44	0.003	2	0	ASA Heavy M. C. Heat Treated Nuts and Hardened, Flat Plate Washers
	"	"	3	39.0	30.1	8.9	23	0.001	0	0	
			Avg.	39.5	26.3	13.2	33	0.002	2	0	
S. W. Corner Reliance Double Coil Hy-Crome Spring Washers	1	1	1	40.0	26.5	13.5	34	0.012	0	0	ASA Heavy M. C. Nuts
	"	"	2	40.0	33.4	6.6	16	0.009	0	0	
	"	"	3	38.7	30.5	8.2	21	0.008	0	0	
			Avg.	39.6	30.1	9.5	24	0.010	0	0	

*Each corner of the crossing has 12-1 3/8-in by 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

TABLE 10 SUMMARY OF THE NINTH CYCLE OF LOSS IN TENSION IN THE NO. 1 BOLTS OF THE BOLTED RAIL CROSSING BETWEEN THE EASTWARD MAIN OF THE PENNSYLVANIA R.R. AND THE SINGLE TRACK BRANCH LINE OF THE NEW YORK CENTRAL SYSTEM AT WARSAW, INDIANA.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Average Bolt Tension (1000 lb)			Percent Tension Lost	Remarks
	Fig. No.	Cv. No.		Initial	Final	Lost		
N. W, Corner Hubbard Experimental Spring Washers	1	9	1-N	40.2	28.9	11.3	28	ASA Heavy M. C. Heat Treated Nuts and Hardened, Flat Plate Washers
	"	"	1-S	41.6	31.6	10.0	24	
	"	"	1-W	41.6	19.7	21.9	53	
	"	"	1-E	38.8	19.0	19.8	51	
			Avg.	40.6	24.8	15.8	39	
N. E. Corner PRR Specification Spring Washers	1	12	1-N	40.0	26.6	13.4	34	ASA Heavy M. C. Nuts
	"	"	1-S	40.6	23.0	17.6	43	
	"	"	1-W	41.3	24.5	16.8	41	
	"	"	1-E	39.3	19.2	20.1	51	
			Avg.	40.3	23.3	17.0	42	
S. E. Corner Reliance Frog and Crossing Hy-Crome Spring Washers	1	8	1-N	38.8	28.9	9.9	26	ASA Heavy M. C. Heat Treated Nuts and Hardened, Flat Plate Washers
	"	"	1-S	40.2	30.9	9.3	23	
	"	"	1-W	40.9	25.8	15.1	37	
	"	"	1-E	40.2	32.3	7.9	19	
			Avg.	40.0	29.5	10.5	26	
S. W. Corner Reliance Double Coil Hy-Crome Spring Washers	1	1	1-N	41.4	30.0	11.4	28	ASA Heavy M. C. Nuts
	"	"	1-S	40.7	30.0	10.7	26	
	"	"	1-W	39.3	31.4	7.9	20	
	"	"	1-E	42.1	26.1	16.0	38	
			Avg.	40.9	29.4	11.5	28	

*Each corner of the crossing has 12-1 3/8-in by 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

These results cover the period from April 17, 1953 to July 7, 1953.

TABLE 11. Percent Tension Loss of 40,000 lb Initial Tension for the 1 3/8 in Main Bolts in the Eastward Crossing between the PRR and NYC at Warsaw, Indiana

Name of Washer		First Cycle 7-12-49 to 11-9-49	Second Cycle 11-9-49 to 6-6-50	Fourth Cycle 10-25-50 to 5-16-51	Sixth Cycle 10-16-51 to 5-14-52	Eighth Cycle 10-2-52 to 4-17-53	No. 1 Bolts		All Bolts	
							Avg.	Percent	Avg.	Percent
PRR Standard Spring Washers	Corner of Crossing No. 1 Bolts All Bolts	NW 58 46 See Note A	NW 74 62 See Note A	NE 73 51 ASA Reg. M. C. Nuts	NE 64 54 ASA Heavy M. C. Nuts	Two 3-mo. cycles omitted	67	100	53	100
Hubbard Experimental Spring Washers	Corner of Crossing No. 1 Bolts All Bolts	NE 55 43 See Note A	NE 64 50 See Note A	NW 60 53 ASA Heavy M. C. Nuts	NW 46 39 ASA Heavy H.T. M.C. Nuts. Hardened plate washers next to corner braces	Two 3-mo. cycles omitted	56	84	46	87
Reliance Heavy Duty Hy-Crome Spring Washers	Corner of Crossing No. 1 Bolts All Bolts		SE 66 52 ASA Reg. M. C. Nuts	SE 65 50 ASA Heavy H.T. M.C. Nuts	SE 56 50 ASA Heavy H.T. M.C. Nuts. Hardened plate washers next to corner braces		62	93	51	96
Type D-5 Compression Washers	Corner of Crossing No. 1 Bolts All Bolts	SW 44 36 See Note A	SW 55 47 See Note A				50	75	42	79
S-300 Plate Washers	Corner of Crossing No. 1 Bolts All Bolts			SW 50 46 See Note A. Two first lot washers nested normally on No. 1 bolts	SW 41 36 ASA Heavy M.C. Nuts. Two second lot washers back to back on No. 1 bolts only		46	69	41	77
Double Coil Hy-Crome Spring Washers	Corner of Crossing No. 1 Bolts All Bolts					SW 34 24 ASA Heavy M. C. Nuts. Double Coil Hy-Crome Washers after 5-14-52	34	51	24	45

Note A: Half L. C. Locknuts and half ASA Reg. M. C. Nuts M. C. = medium carbon H. T. = heat treated L. C. = low carbon

TABLE 12. SUMMARY OF THE FIRST CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF TWO BOLTED RAIL CROSSINGS BETWEEN THE EASTWARD TRACK OF THE PENNSYLVANIA R. R. AND THE DOUBLE TRACK MAIN OF THE G. M. &O. R. R., 37th STREET AND CAMPBELL AVE., CHICAGO, ILLINOIS.

Location and Name of Spring Washers	Washer Curve Reference		*Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost			20 K	10 K	
NORTHWEST CROSSING "C"											
East Half	1	9	1	40.2	24.2	16.0	40	0.015	2	1	ASA Regular M. C. Nuts
Hubbard Experimental	"	"	2	40.4	26.4	14.0	35	0.009	1	1	
Spring Washers	"	"	3	41.3	32.6	8.7	21	0.006	0	0	
			Avg.	40.6	27.7	12.4	33	0.010	3	2	
West Half	1	11	1	41.9	17.0	24.9	59	0.011	5	2	ASA Regular M. C. Nuts
Used PRR Spec.	"	"	2	44.9	31.9	13.0	29	0.006	2	0	
Spring Washers	"	"	3	39.5	32.9	6.6	17	0.004	0	0	
			Avg.	42.2	27.2	15.1	36	0.007	7	2	
SOUTHWEST CROSSING "D"											
East Half	1	8	1	38.7	21.1	17.6	45	0.017	3	1	ASA Regular M. C. Nuts
Improved Frog and	"	"	2	42.8	29.5	13.3	31	0.011	1	0	
Crossing Hy-Crome	"	"	3	41.9	33.1	8.8	21	0.008	0	0	
Spring Washers			Avg.	41.1	27.9	13.2	32	0.012	4	1	
West Half	1	11	1	43.1	20.4	22.7	53	0.015	1	1	ASA Regular M. C. Nuts
Used PRR Spec.	"	"	2	41.3	28.1	13.2	32	0.013	0	0	
Spring Washers	"	"	3	40.2	30.1	10.1	25	0.009	0	0	
			Avg.	41.5	26.2	15.1	36	0.012	1	1	

*Each half of a crossing has 24-1 3/8-in x 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of each corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

These results cover the period from June 15, 1949 to October 12, 1949.

TABLE 13 SUMMARY OF THE SECOND CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF TWO BOLTED RAIL CROSSINGS BETWEEN THE EASTWARD TRACK OF THE PENNSYLVANIA R. R. AND THE DOUBLE TRACK MAIN OF THE G. M. &O. R. R., 37th STREET AND CAMPBELL AVE., CHICAGO, ILLINOIS.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost			20 K	10 K	
NORTHWEST CROSSING "C"											
East Half	1	9	1	39.6	12.6	27.0	68	0.031	7	2	ASA Regular M. C. Nuts
Hubbard Experimental	"	"	2	39.9	18.7	21.2	53	0.023	5	1	
Spring Washers	"	"	3	38.8	24.9	13.9	36	0.017	4	0	
			Avg.	39.4	18.7	20.7	53	0.024	16	3	
West Half	1	11	1	39.3	10.1	29.2	74	0.022	8	3	ASA Regular M. C. Nuts
Used PRR Spec.	"	"	2	39.8	19.9	19.9	50	0.021	4	2	
Spring Washers	"	"	3	41.0	17.2	23.8	58	0.021	2	1	
			Avg.	39.9	15.3	24.6	62	0.021	14	6	
SOUTHWEST CROSSING "D"											
East Half	1	8	1	37.5	11.8	25.7	69	0.019	6	4	ASA Regular M. C. Nuts
Improved Frog and	"	"	2	37.6	20.5	17.1	46	0.013	4	2	
Crossing Hy-Crome	"	"	3	38.2	20.9	17.3	45	0.012	3	1	
Spring Washers			Avg.	37.8	17.7	20.1	53	0.015	13	7	
West Half	1	11	1	40.1	5.2	34.9	87	0.027	7	6	ASA Regular M. C. Nuts
Used PRR Spec.	"	"	2	39.7	17.4	22.3	56	0.018	5	2	
Spring Washers	"	"	3	35.9	20.5	15.4	43	0.015	4	2	
			Avg.	38.6	14.9	23.7	61	0.019	16	10	

*Each half of a crossing has 24- 1 3/8-in x 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of each corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

These results cover the period from October 12, 1949 to June 21, 1950.

TABLE 14. SUMMARY OF THE THIRD CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF TWO BOLTED RAIL CROSSINGS BETWEEN THE EASTWARD TRACK OF THE PENNSYLVANIA R.R. AND THE DOUBLE TRACK MAIN OF THE G. M. &O. R. R., 37th STREET AND CAMPBELL AVE., CHICAGO, ILLINOIS.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost			20 K	10 K	
NORTHWEST CROSSING "C"											
East Half	3	3	1	24.4	10.6	13.8	57	0.015	8	4	ASA Regular M. C. Nuts
Hubbard Experimental	"	"	2	24.7	12.6	12.1	49	0.013	7	2	
Spring Washers	"	"	3	25.5	17.2	8.3	33	0.015	5	1	
			Avg.	24.8	13.3	11.5	46	0.014	20	7.	
West Half	3	6	1	23.4	12.2	11.2	48	0.015	8	3	ASA Regular M.C. Nuts
Used PRR Spec.	"	"	2	24.4	14.9	9.5	39	0.011	3	2	
Spring Washers	"	"	3	24.8	14.7	10.1	41	0.020	4	2	
			Avg.	24.1	13.7	10.4	43	0.016	15	7	
SOUTHWEST CROSSING "D"											
East Half	3	4	1	24.5	9.9	14.6	60	0.017	8	3	ASA Regular M.C. Nuts
Improved Frog and	"	"	2	24.9	13.9	11.0	44	0.023	6	3	
Crossing Hy-Crome	"	"	3	25.3	17.9	7.4	29	0.027	4	1	
Spring Washers			Avg.	24.9	13.9	11.0	44	0.023	18	7	
West Half	3	6	1	25.1	6.1	19.0	76	0.015	8	7	ASA Regular M.C. Nuts
Used PRR Spec.	"	"	2	25.5	10.5	15.0	59	0.022	6	4	
Spring Washers	"	"	3	25.2	12.5	12.7	50	0.025	5	3	
			Avg.	25.3	9.6	15.7	62	0.021	19	14	

*Each half of the crossing had 24-1 3/8-in by 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of each corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

These results cover the period from June 21, 1950 to January 11, 1951.

TABLE 15 SUMMARY OF THE FOURTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF TWO BOLTED RAIL CROSSINGS BETWEEN THE EASTWARD TRACK OF THE PENNSYLVANIA R.R. AND THE DOUBLE TRACK MAIN OF THE G.M. &O.R.R., 37th STREET AND CAMPBELL AVE., CHICAGO, ILLINOIS.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost			20 K	10 K	
NORTHWEST CROSSING "C"											
East Half Hubbard Experimental Spring Washers	3	3	1	25.1	13.4	11.7	47	0.013	8	0	ASA Regular M.C. Nuts
	"	"	2	24.6	11.7	12.9	52	0.020	7	3	
	"	"	3	25.1	13.7	11.4	45	0.018	6	2	
			Avg.	24.9	12.9	12.0	48	0.017	21	5	
West Half Used PRR Spec. Spring Washers	3	6	1	25.3	7.8	17.5	69	0.016	7	5	ASA Regular M.C. Nuts
	"	"	2	25.2	7.3	17.9	71	0.011	6	6	
	"	"	3	24.7	6.3	18.4	75	0.017	5	5	
			Avg.	25.1	7.2	17.9	71	0.015	18	16	
SOUTHWEST CROSSING "D"											
East Half Improved Frog and Crossing Hy-Crome Spring Washers	3	4	1	26.2	4.7	21.5	82	0.018	8	7	ASA Regular M.C. Nuts
	"	"	2	24.8	7.7	17.1	69	0.017	8	4	
	"	"	3	24.6	11.2	13.4	54	0.016	5	3	
			Avg.	25.2	7.7	17.5	69	0.017	21	14	
West Half Used PRR Spec. Spring Washers	3	6	1	24.8	4.8	20.0	81	0.012	7	7	ASA Regular M.C. Nuts
	"	"	2	25.4	6.3	19.1	75	0.013	8	6	
	"	"	3	24.5	9.7	14.8	61	0.016	7	5	
			Avg.	24.9	7.0	17.9	72	0.014	22	18	

*Each half of the crossing has 24-1 3/8-in by 14-in main bolts. The No. 1 bolt position is the nearest one to the flangeway intersection in the four arms of each corner, the No. 2 position the next nearest one, and the No. 3 the farthest from the intersection.

These results cover the period from January 11, 1951 to October 10, 1951.

TABLE 16. SUMMARY OF THE THIRD CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE CROSSING BETWEEN THE SOUTHWARD TRACK OF THE C.&W.I.R.R. AND THE WESTWARD TRACK OF THE I.H.B.R.R., 55th STREET AND CICERO AVE., CHICAGO, ILLINOIS.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost			20 K	10 K	
NORTHWEST CROSSING "A" - Manganese Insert on T-Beam Support											
N.W. Corner	-	-	1	26.0	2.2	23.8	92	0.010	4	4	ASA Regular Hex, L.C.
No Spring Washers	-	-	2	25.0	15.0	10.0	40	0.009	2	1	Elastic Stop Nuts
	-	-	3	25.1	22.2	2.9	12	0.013	1	0	
			Avg.	25.4	12.3	13.1	52	0.010	7	5	
S.W. Corner	6	2	1	25.3	6.7	18.6	74	0.017	4	3	ASA Regular Hex,
Used Hy-Pressure	"	"	2	25.7	16.3	9.4	37	0.013	3	0	L.C. Elastic Stop Nuts
Hy-Crome Spring Washers	"	"	3	25.3	20.3	5.0	20	0.011	2	0	
			Avg.	25.4	14.4	10.0	39	0.014	9	3	
N.E. Corner	6	2	1	25.3	8.4	16.9	67	0.016	4	3	ASA Heavy, 1/4-in
Used Hy-Pressure	"	"	2	25.6	22.4	3.2	12	0.015	1	0	extra thick M.C. Nuts
Hy-Crome Spring Washers	"	"	3	25.6	20.5	5.1	20	0.012	2	1	
			Avg.	25.5	17.1	8.4	33	0.014	7	4	
S.E. Corner	6	3	1	25.2	10.0	15.2	60	0.014	4	2	ASA Heavy, 1/4-in
Used Standard	"	"	2	25.2	16.7	8.5	34	0.013	3	1	extra thick M.C. Nuts
Hy-Crome Spring Washers	"	"	3	25.3	17.9	7.4	29	0.015	2	0	
			Avg.	25.2	14.6	10.6	42	0.014	9	3	

*Each corner of the crossing has 12-1 1/4-in main bolts, 4 each of three lengths. The No. 1 bolt position is the one nearest the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest one,and the No. 3 the farthest from the intersection.

These results cover the period from July 17, 1950 to April 20, 1951.

See Vol. 52, 1951, Page 547, Table 6 for second test cycle.

TABLE 17. SUMMARY OF THE THIRD CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE CROSSING BETWEEN THE DOUBLE TRACK OF THE C.&W.I. R.R. AND THE EASTWARD TRACK OF THE I. H. B. R. R., 55th STREET AND CICERO AVE., CHICAGO, ILLINOIS.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost			20 K	10 K	
SOUTHWEST CROSSING "C" - Manganese Insert on Framed Timbers - 1 1/4-in Bolts											
East half Used Standard Hy-Crome Spring Washers	6	3	1	24.8	5.5	19.3	78	0.008	8	7	ASA Heavy, 1/4-in extra thick M. C. Nuts
	"	"	2	25.3	10.3	15.0	59	0.010	7	4	
	"	"	3	25.4	17.3	8.1	32	0.011	4	1	
			Avg.	25.2	11.0	14.2	56	0.010	19	12	
West half New Improved Frog and Crossing Hy-Crome Spring Washers, replacing 1 3/8-in size	6	1	1	25.4	6.1	19.3	76	0.008	8	7	ASA Heavy, 1/4-in extra thick M. C. Nuts
	"	"	2	24.8	13.6	11.2	45	0.009	7	2	
	"	"	3	26.0	17.1	8.9	34	0.013	5	0	
			Avg.	25.4	12.0	13.4	53	0.010	20	9	
SOUTHEAST CROSSING "D" - Solid Manganese on Framed Timbers											
1 3/8-in Interior Bolts Used Hy-Pressure Hy-Crome Spring Washers	3	5	1	24.2	15.2	9.0	37	0.011	5	1	ASA Heavy, 1/4-in extra thick M. C. Nuts
	"	"	2	24.9	15.6	9.3	37	0.010	5	1	
	"	"	3	25.0	15.6	9.4	38	0.008	7	1	
			Avg.	24.7	15.5	9.2	37	0.010	17	3	
1 1/4-in Exterior Bolts Used Hy-Pressure Hy-Crome Spring Washers	6	2	1	25.0	15.4	9.6	38	0.010	5	0	ASA Heavy, 1/4-in extra thick M. C. Nuts
	"	"	2	25.4	20.0	5.4	21	0.009	2	1	
	"	"	3	25.7	15.8	9.9	38	0.010	7	1	
	"	"	4	26.0	18.4	7.6	29	0.011	3	1	
			Avg.	25.5	17.4	8.1	32	0.010	17	3	

*Crossing "C" has the same arrangement of bolts as Crossing "A". New 1 1/4-in spring washers were placed on the west half of Crossing "C", July 17, 1950.

Crossing "D". - Each external arm has four main bolts for connecting the rails to the casting, and the bolts are numbered from flangeway intersection to the far end of the connecting joint. Each interior side of the crossing has a six-hole joint. Bolt position 3 includes the two middle bolts of the joint, position 2, the intermediate bolts, and position 1, the end bolts of the internal joints.

These results cover the period from July 17, 1950 to April 20, 1951 for Crossing "C" and from July 17, 1950 to January 18, 1951 for Crossing "D".

See Vol. 52, 1951, Page 550, Table 7 for second test cycle

TABLE 18. SUMMARY OF THE FOURTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE CROSSING BETWEEN THE SOUTHWARD TRACK OF THE C.&W.I.R.R. AND THE WESTWARD TRACK OF THE I.H.B.R.R., 55th STREET AND CICERO AVE., CHICAGO, ILLINOIS.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost		20 K	10 K	
NORTHWEST CROSSING "A" - Manganese Insert on T-Beam Support										
N.W. Corner Used Hy-Pressure Hy-Crome Spring Washers	5	2	1	31.3	13.8	17.5	56	4	1	ASA Regular Hex, L.C. Elastic Stop Nuts
	"	"	2	29.7	18.5	11.2	38	3	0	
	"	"	3	29.2	23.2	6.0	20	0	0	
			Avg.	30.1	18.5	11.6	39	7	1	
S.W. Corner No Spring Washers	-	-	1	30.2	8.1	22.1	73	3	2	ASA Regular Hex, L.C. Elastic Stop Nuts
	-	-	2	28.6	17.9	10.7	37	3	0	
	-	-	3	30.2	20.7	9.5	31	2	0	
			Avg.	29.6	16.2	13.4	45	8	2	
N.E. Corner Used Hy-Pressure Hy-Crome Spring Washers	5	2	1	30.0	15.2	14.8	49	3	0	ASA Heavy, 1/4-in extra thick M.C. Nuts
	"	"	2	30.4	17.2	13.2	43	4	0	
	"	"	3	30.3	28.2	2.1	7	0	0	
			Avg.	30.2	17.5	12.7	42	7	0	
S.E. Corner Used Standard Hy-Crome Spring Washers	5	3	1	30.1	12.2	17.9	60	4	1	ASA Heavy, 1/4-in extra thick M.C. Nuts
	"	"	2	30.7	15.8	14.9	49	3	1	
	"	"	3	32.3	30.8	1.5	5	0	0	
			Avg.	30.9	18.6	12.3	40	7	2	

*Each corner of the crossing has 12-1 1/4-in main bolts, 4 each of three lengths. The No. 1 bolt position is the one nearest the flangeway intersection in the four arms of a corner, the No. 2 position the next nearest, and the No. 3 the farthest from the intersection.

Pull-in measurements were omitted from tabulation because of inconsistent results.

These results cover the period from April 20, 1951 to November 1, 1951.

TABLE 19. SUMMARY OF THE FOURTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE CROSSINGS BETWEEN THE DOUBLE TRACK LINE OF THE C.&W.I.R.R. AND THE EASTWARD TRACK OF THE I.H.B.R.R., 55th STREET AND CICERO AVE., CHICAGO, ILLINOIS.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig.No.	Cv.No.		Initial	Final	Lost			20 K	10 K	
SOUTHWEST CROSSING "C" - Manganese Insert on Framed Timbers - 1 1/4-in Bolts											
East Half	5	4	1	29.9	15.9	14.0	47	0.010	7	2	New ASA Heavy, 1/4-in
New Standard	"	"	2	30.2	21.1	9.1	30	0.003	5	0	extra thick M. C. Nuts
Hy-Crome Spring	"	"	3	30.1	24.3	5.8	19	0.004	1	0	
Washers			Avg.	30.1	20.1	10.0	33	0.006	13	2	
West Half	5	1	1	30.4	21.1	9.3	31	0.006	4	0	New ASA Heavy, 1/4-in
Improved Frog and	"	"	2	30.0	22.8	7.2	24	0.002	1	0	extra thick M. C. Nuts
Crossing Hy-Crome	"	"	3	30.2	26.0	4.2	14	0.006	1	0	
Spring Washers			Avg.	30.2	23.0	7.2	24	0.005	6	0	
SOUTHEAST CROSSING "D" - Solid Manganese on Framed Timbers											
1 3/8-in Interior	3	5	1	25.5	11.3	14.2	56	0.023	5	4	ASA Heavy, 1/4-in extra
Bolts Used Hy-Pressure	"	"	2	24.5	10.5	14.0	57	0.011	8	4	thick M. C. Nuts
Hy-Crome Spring	"	"	3	25.7	11.0	14.7	57	0.008	8	3	
Washers			Avg.	25.2	10.9	14.3	57	0.014	21	11	
1 1/4-in Exterior	6	2	1	25.1	13.4	11.7	47	0.013	5	2	ASA Heavy, 1/4-in extra
Bolts Used Hy-Pressure	"	"	2	24.9	11.9	13.0	52	0.010	7	3	thick M. C. Nuts
Hy-Crome Spring	"	"	3	24.6	12.0	12.6	51	0.012	6	4	
Washers	"	"	4	25.5	13.6	11.9	47	0.010	7	1	
			Avg.	25.0	12.7	12.3	49	0.011	25	10	

*Crossing "C" has the same arrangement of bolts as Crossing "A". The following changes were made to Crossing "C", June 1, 1951: (1) New nuts, faced, were applied to all main bolts, (2) all beveled washers and headlocks were welded to the corner braces, and (3) new spring washers were applied to the east half of the crossing.

Crossing "D". - Each external arm has four main bolts for connecting the rails to the casting, and the bolts are numbered from the flangeway intersection to the far end of the connecting joint. Each interior side of the crossing has a six-hole joint. Bolt position 3 includes the two middle bolts of the joint, position 2, the intermediate bolts, and position 1, the end bolts of the internal joints.

These results cover the period from June 1, 1951 to November 1, 1951 for Crossing "C" and from January 19, 1951 to October 3, 1951 for Crossing "D".

TABLE 20. SUMMARY OF THE FIFTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE CROSSINGS BETWEEN THE DOUBLE TRACK LINE OF THE C. &W. I. R. R. AND THE EASTWARD TRACK OF THE I. H. B. R. R., 55th STREET AND CICERO AVE., CHICAGO, ILLINOIS.

Location and Name of Spring Washers	Washer Curve Reference Fig.No.	Cv.No.	* Bolt Position	Avg. Bolt Tension (1000 lb) Initial	Final	Lost	Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than 20 K	10 K	Remarks
SOUTHWEST CROSSING "C" - Manganese Insert on Framed Timbers - 1 1/4-in Bolts											
East Half	4	4	1	40.1	15.3	24.8	62	0.010	5	2	ASA Heavy, 1/4-in
Standard Hy-Crome	"	"	2	39.9	29.0	10.9	27	0.009	0	0	extra thick M. C. Nuts
Spring Washers	"	"	3	39.5	33.0	6.5	16	0.012	0	0	
			Avg.	39.8	25.8	14.0	35	0.010	5	2	
West Half	4	1	1	40.7	20.1	20.6	51	0.006	4	0	ASA Heavy, 1/4-in
Improved Frog and	"	"	2	40.7	28.7	12.0	30	0.008	0	0	extra thick M. C. Nuts
Crossing Hy-Crome	"	"	3	39.8	32.6	7.2	18	0.010	0	0	
Spring Washers			Avg.	40.4	27.1	13.3	33	0.008	4	0	
SOUTHEAST CROSSING "D" - Solid Manganese on Framed Timbers											
1 3/8-in Interior	1	10	1	40.3	17.0	23.3	58	0.014	6	2	ASA Heavy, 1/4-in
Bolts Used Hy-Pressure	"	"	2	39.4	13.8	25.6	65	0.010	7	1	extra thick M. C. Nuts
Hy-Crome Spring	"	"	3	39.7	13.2	26.5	67	0.005	7	2	
Washers			Avg.	39.8	14.7	25.1	63	0.009	20	5	
1 1/4-in Exterior	4	2	1	40.0	15.5	24.5	61	0.004	6	2	ASA Heavy, 1/4-in
Bolts Used Hy-Pressure	"	"	2	39.6	16.7	22.9	58	0.005	4	1	extra thick M. C. Nuts
Hy-Crome Spring	"	"	3	40.3	14.3	26.0	64	0.008	6	2	
Washers	"	"	4	40.2	13.4	26.8	67	0.008	8	2	
			Avg.	40.0	15.0	25.0	62	0.006	24	7	

*Crossing "C" has the same arrangement of bolts as Crossing "A".

Crossing "D". - Each external arm has four main bolts for connecting the rails to the casting, and the bolts are numbered from the flangeway intersection to the far end of the connecting joint. Each interior side of the crossing has a six-hole joint. Bolt position 3 includes the two middle bolts of the joint, position 2, the intermediate bolts, and position 1, the end bolts of the internal joint.

These results cover the period from November 1, 1951 to May 21, 1952 for Crossing "C" and from October 3, 1951 to May 21, 1952 for Crossing "D".

TABLE 21. SUMMARY OF THE SIXTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE CROSSINGS BETWEEN THE DOUBLE TRACK LINE OF THE C. &W. I. R. R. AND THE EASTWARD TRACK OF THE I. H. B. R. R., 55th STREET AND CICERO AVE., CHICAGO, ILLINOIS.

Location and Name of Spring Washers	Washer Curve Reference		* Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig. No.	Cv. No.		Initial	Final	Lost			20 K	10 K	
SOUTHWEST CROSSING "C" - Manganese Insert on Framed Timbers - 1 1/4-in Bolts											
East Half Standard Hy-Crome Spring Washers	5	4	1	29.8	18.5	11.3	38	0.008	6	0	ASA Heavy, 1/4-in extra thick M. C. Nuts
	"	"	2	29.8	24.8	5.0	17	0.005	0	0	
	"	"	3	30.2	30.1	0.1	3	0.002	0	0	
			Avg.	29.9	24.5	5.4	18	0.005	6	0	
West Half Improved Frog and Crossing Hy-Crome Spring Washers	5	1	1	30.3	21.3	9.0	30	0.008	3	0	ASA Heavy, 1/4-in extra thick M. C. Nuts
	"	"	2	29.6	27.7	1.9	6	0.005	0	0	
	"	"	3	30.6	29.1	1.5	5	0.002	0	0	
			Avg.	30.2	26.0	4.2	14	0.005	3	0	
SOUTHEAST CROSSING "D" - Solid Manganese on Framed Timbers											
1 3/8-in Interior Bolts Used Hy-Pressure Hy-Crome Spring Washers	2	6	1	29.6	23.7	5.9	20	0.007	2	0	ASA Heavy, 1/4-in extra thick M. C. Nuts
	"	"	2	29.3	17.0	12.3	42	0.010	6	1	
	"	"	3	30.0	13.6	16.4	55	0.011	7	1	
			Avg.	29.6	18.1	11.5	39	0.009	15	2	
1 1/4-in Exterior Bolts Used Hy-Pressure Hy-Crome Spring Washers	5	2	1	29.7	23.9	5.8	20	0.012	7	3	ASA Heavy, 1/4-in extra thick M. C. Nuts
	"	"	2	29.7	15.8	13.9	47	0.010	5	1	
	"	"	3	29.7	16.5	13.2	44	0.010	7	2	
	"	"	4	29.3	13.6	15.7	54	0.010	2	1	
			Avg.	29.6	17.4	12.2	41	0.010	21	7	

*Crossing "C" has the same arrangement of bolts as Crossing "A".

Crossing "D". - Each external arm has four main bolts for connecting the rails to the casting, and the bolts are numbered from the flangeway intersection to the far end of the connecting joint. Each interior side of the crossing has a six-hole joint. Bolt position 3 includes the two middle bolts of the joint, position 2, the intermediate bolts, and position 1, the end bolts of the internal joint.

These results cover the period from May 21, 1952 to October 7, 1952.

TABLE 22. SUMMARY OF THE SEVENTH CYCLE OF LOSS IN TENSION IN THE MAIN BOLTS OF THE CROSSINGS BETWEEN THE DOUBLE TRACK LINE OF THE C. &W. I. R. R. AND THE EASTWARD TRACK OF THE I. H. B. R. R., 55th STREET AND CICERO AVE., CHICAGO, ILLINOIS.

Location and Name of Spring Washers	Washer Curve Reference		Bolt Position	Avg. Bolt Tension (1000 lb)			Percent Tension Lost	Average Pull-in (in)	No. of Bolts with Final Tension less than		Remarks
	Fig. No.	Cv. No.		Initial	Final	Lost			20 K	10 K	
SOUTH EAST CROSSING "D" - Solid Manganese on Framed Timbers											
1 3/8-in Interior Bolts Used Hy-Pressure Hy-Crome Spring Washers	1	10	1	39.6	29.8	9.8	25	0.005	2	0	ASA Heavy, 1/4-in extra thick M. C. Nuts
	"	"	2	40.2	22.6	17.6	44	0.006	3	0	
	"	"	3	39.1	16.6	22.5	58	0.008	6	1	
			Avg.	39.6	23.0	16.6	42	0.006	11	1	
1 1/4-in Exterior Bolts Used Hy-Pressure Hy-Crome Spring Washers	4	2	1	39.9	19.1	20.8	52	0.005	4	1	ASA Heavy, 1/4-in extra thick M. C. Nuts
	"	"	2	39.6	16.2	23.4	59	0.007	6	1	
	"	"	3	39.7	13.4	26.3	66	0.012	6	3	
	"	"	4	40.1	19.6	20.5	51	0.014	4	0	
			Avg.	39.8	17.1	22.8	57	0.010	20	5	

Crossing "D". - Each external arm has four main bolts for connecting the rails to the casting, and the bolts are numbered from the flangeway intersection to the far end of the connecting joint. Each interior side of the crossing has a six-hole joint. Bolt position 3 includes the two middle bolts of the joint, position 2, the intermediate bolts, and position 1, the end bolts of the internal joint.

These results cover the period from October 7, 1952 to April 22, 1953.

TABLE 23. - SUMMARY OF THE FIRST CYCLE OF LOSS IN TENSION IN THE 1 3/8 IN DIA. BOLTS OF A NO. 15 - 25 FT - 140 PS RAILBOUND MANGANESE TURNOUT FROG IN THE WESTWARD MAIN AND CROSSOVER OF THE PENNSYLVANIA RAILROAD AT WARSAW, INDIANA.

Bolt No.	Nominal Length (in)	Bolt Tension in 1,000 lb			Percent Tension Lost	Average Pull-in (in)
		Initial	Final	Lost		
Bolts Ahead of Point of Frog						
5-T	11	40.0	25.2	14.8	37	0.014
4-T	11	40.6	35.1	5.5	14	0.001
3-T	14	41.0	38.8	2.2	5	0.001
2-T	15	39.8	39.1	0.7	2	0.004
1-T	15	41.3	41.3	0.0	0	0.001
Avg.		40.5	35.9	4.6	11	0.004
Bolts Behind Point of Frog						
1-H	15	41.8	41.8	0.0	0	0.001
2-H	18	41.3	30.6	10.7	26	0.002
3-H	18	41.3	23.6	17.7	43	0.004
4-H	18	42.0	25.0	17.0	40	0.006
5-H	18	40.0	30.5	9.5	24	0.006
6-H	18	41.5	23.5	18.0	43	0.002
7-H	18	40.6	40.6	0.0	0	0.000
8-H	18	40.4	29.1	11.3	28	0.002
9-H	18	39.5	30.0	9.5	24	0.007
10-H	9	39.8	34.0	5.8	15	0.007
11-H	9	40.0	21.3	18.7	47	0.016
12-H	11½	47.6	31.6	16.0	34	0.003
13-H	12	49.8	38.1	11.7	23	0.000
Avg.		41.9	30.7	11.2	27	0.004
Avg. All		41.6	32.2	9.4	23	0.004

The bolts are numbered each way from the actual point of frog which is located between bolt Nos. 1-T and 1-H. All bolts have PRR Specification Spring Washers.

These results cover the period from May 3, 1950 to August 15, 1951 (1.28 years).

TABLE 24. - SUMMARY OF THE SECOND CYCLE OF LOSS IN TENSION IN THE 1 3/8 IN DIA. BOLTS OF A NO. 15 - 25 FT - 140 PS RAILBOUND MANGANESE TURNOUT FROG IN THE WESTWARD MAIN AND CROSSOVER OF THE PENNSYLVANIA RAILROAD AT WARSAW, INDIANA.

Bolt No.	Nominal Length (in)	Bolt Tension in 1,000 lb			Percent Tension Lost	Average Pull-in (in)
		Initial	Final	Lost		
Bolts Ahead of Point of Frog						
5-T	11	37.2	30.2	7.0	19	0.001
4-T	11	40.8	27.3	13.5	33	0.003
3-T	14	40.4	38.8	1.6	4	0.002
2-T	15	40.3	34.9	5.4	13	0.002
1-T	15	38.6	30.0	8.6	22	0.002
Avg.		39.4	32.2	7.2	18	0.002
Bolts Behind Point of Frog						
1-H	15	41.8	35.1	6.7	16	0.000
2-H	18	41.2	23.2	18.0	44	0.001
3-H	18	39.9	23.3	16.6	42	0.002
4-H	18	41.8	25.0	16.8	40	0.005
5-H	18	39.4	26.2	13.2	33	0.001
6-H	18	39.1	21.2	17.9	46	0.004
7-H	18	41.1	31.8	9.3	23	0.002
8-H	18	39.3	26.2	13.1	33	0.001
9-H	18	38.7	18.3	20.4	53	0.002
10-H	9	40.4	28.9	11.5	28	0.007
11-H	9	41.2	27.4	13.8	33	0.004
12-H	11½	40.9	29.1	11.8	29	0.006
13-H	12	41.5	34.2	7.3	18	0.006
Avg.		40.5	26.9	13.6	34	0.003
Avg. All		40.2	28.4	11.8	29	0.003

The bolts are numbered each way from the actual point of frog which is located between bolt Nos. 1-T and 1-H. All bolts have Frog and Crossing Hy-Crome Spring Washers.

These results cover the period from August 15, 1951 to August 14, 1952 (1.00 year).

TABLE 25. - SUMMARY OF THE THIRD CYCLE OF LOSS IN TENSION IN THE 1 3/8 IN DIA. BOLTS OF A NO. 15 - 25 FT - 140 PS RAILBOUND MANGANESE TURNOUT FROG IN THE WESTWARD MAIN AND CROSSOVER OF THE PENNSYLVANIA RAILROAD AT WARSAW, INDIANA.

Bolt No.	Nominal Length (in)	Bolt Tension in 1,000 lb			Percent Tension Lost	Average Pull-in (in)
		Initial	Final	Lost		
Bolts Ahead of Point of Frog						
5-T	11	38.0	25.1	12.9	34	0.000
4-T	11	42.5	29.9	12.6	30	0.002
3-T	15	39.6	37.3	2.3	6	0.001
2-T	15	41.7	40.1	1.6	4	0.001
1-T	15	40.0	37.9	2.1	5	0.003
Avg.		40.4	34.1	6.3	16	0.001
Bolts Behind Point of Frog						
1-H	15	39.7	36.5	3.2	8	0.004
2-H	18	40.0	31.9	8.1	20	0.002
3-H	18	38.4	25.6	12.8	33	0.002
4-H	18	41.3	22.4	18.9	46	0.002
5-H	18	39.4	23.0	16.4	42	0.000
6-H	18	38.6	24.6	14.0	36	0.001
7-H	18	39.4	32.4	7.0	17	0.006
8-H	18	39.3	26.8	12.5	32	0.005
9-H	18	38.6	31.0	7.6	20	0.002
10-H	11	38.2	30.0	8.2	22	0.002
11-H	11	42.2	33.8	8.4	20	0.005
12-H	15	40.0	33.3	6.7	17	0.002
13-H	15	39.9	38.0	1.9	48	0.004
Avg.		39.6	29.9	9.7	24	0.003
Avg. All		39.8	31.1	8.7	22	0.002

The bolts are numbered each way from the actual point of frog which is located between bolt Nos. 1-T and 1-H. All bolts have the Frog and Crossing Hy-Crome Spring Washers.

These results cover the period from August 14, 1952 to July 7, 1953 (0.90 year).

TABLE 26. LOCKNUT TEST IN 1 3/8 IN MAIN BOLTS OF 131-LB HEAT TREATED BOLTED RAIL CROSSING BETWEEN THE WESTBOUND MAIN OF THE PRR AND THE NYC BRANCH TRACK AT WARSAW, IND.

(Values of Maximum Frictional Torque are shown in ft.-lb.)

Bolt Position	ASA Heavy Square Elastic Stop Nuts N. W. Corner		ASA Reg. Hex. Security Nuts N. E. Corner		ASA Reg. Square M. F. Unitary No. 3 Nuts S.W. Corner		
Date	5/50	8/52	5/50	8/52	5/50	8/52	
Col. -	(1)	(2)	(1)	(2)	(1)	(2)	Remarks
1-W	(a)	--	135	15	90	(e)	
2-W	135	20	(300)	25	(300)	(e)	
3-W	105	30	--	--	(c)	(e)	
1-N	(b)	--	*120	20	205	25	
2-N	120	10	*75	30	120	5	Averages exclude values shown in parentheses
3-N	105	0	*75	(180)	180	5	
1-E	165	(e)	90	45	195	0	
2-E	165	5	195	(d)	(315)	(d)	
3-E	135	0	135	(d)	(315)	(d)	
1-S	90	5	*(330)	0	240	0	
2-S	95	15	*105	(e)	180	0	
3-S	120	15	40	(e)	210	25	
Avg.	124	11	108	27	178	9	
(A)	90		135		265		One nut of each type

Col. (1). Frictional torque in ft.-lb. for first application of new nuts (except for the SH Security Nuts).

Col. (2). Frictional torque in ft.-lb. for reapplication of the same nuts, after cleaning and oiling the bolt threads.

(a) Omitted because of damaged threads at end of bolt which prevented application of Elastic Stop nuts without stripping them. (b) Omitted account of torque wrench fouled by another bolt. (c) Omitted account of first thread was battered which caused friction torque to exceed the 675 ft-lb capacity of the torque wrench. (d) Omitted account of bolt and nut had been damaged. (e) Bolt and nut replaced by maintenance forces.
* Second-hand nuts.

Values shown in parentheses are omitted from averages as these high values were caused by damaged threads at the end of the bolts. The locknuts were applied to the bolts May 1, 1950, without oiling the threads. The crossing was installed new in 1947. All locknuts were new, except six Security Nuts had been in service 11 mo. in the eastward crossing.

(A) Frictional torque values obtained for first application of new locknut on new bolt in laboratory, without lubrication.

Part 2

Specifications and Revisions Suggested for Later Consideration As Recommended Practice and Publication in the Manual (Portfolio of Trackwork Plans)

The following recommendations are based upon the results of the 5-year investigation as discussed in Part 1 of this report.

I. Delete Art. 15, Spring Washers, as now published in the Portfolio of Trackwork Plans, Appendix A–52, page 8, reading as follows:

Article 15, Spring Washers

1501. Material Covered

Helical spring washers for use in special trackwork.

1502. Manufacture

Spring washers for all bolts ¾-in diameter and over, shall be in accordance with the current AREA Specifications for Spring Washers.

II. The following revisions and additions are suggested in lieu of the foregoing Art. 15.

Article 15, Spring Washers

1501. Material Covered

Spring washers for use in special trackwork.

1502. Manufacture

Spring washers for all bolts of ¾ in to 1⅜ in diameter, incl., shall be in accordance with the current AREA Specifications for Spring Washers, (Manual, Part 2, Chapter 4), except that for the 1¼-in and 1⅜-in sizes the following revisions and additions to the specifications shall govern:

Method of Testing for Reactive Load

The reactive pressure tests of the specimens shall be conducted in a compression machine of approved design, equipped with a deflection gage graduated in 0.001 in and located so that readings are taken from approximately the center of the platens. Each specimen washer shall be placed in the testing machine between two steel plates not less than ½ in thick, having smoothly ground or machined surfaces and a Brinell hardness of not to exceed 150. Place assembly between the platens of the machine, apply one load of 40,000 lb and record the gage reading for that position of the platens. Increase the test load to 60,000 lb. Release the platens until the distance between them is 0.030 in greater than the gage reading taken at the 40,000 lb load. The minimum reactive load remaining at the above release shall be 10,000 lb.

Ductility Test

This test shall be conducted in accordance with Art. 4, Par. (a) of the current specifications, except double-coil washers shall first be cut off to form a single-coil washer.

Proportion of Tests

Art. 5 of the current specifications shall govern, except that 3 specimens will be tested for each lot of 1000 or more of finished spring washers.

Acknowledgement

This investigation was conducted under the general direction of G. M. Magee, director of engineering research, Engineering Division, AAR. H. E. Durham, research engineer track, AAR, was in direct charge of the assignment and was assisted by A. D. Van Sant, assistant research engineer track, and other staff members.

The success of these tests depended greatly upon the cooperation and assistance rendered by the Pennsylvania Railroad and the Indiana Harbor Belt Railroad, as well as the participating manufacturers. The Association and the committee take pleasure in extending their deep appreciation to these two railroads and the following manufacturers: Eaton Manufacturing Co., Reliance Division; Hubbard & Company; American Brake Shoe Company, Ramapo Ajax Division; National Lock Washer Company; Erico Products, Inc., the locknut companies, and others.

Report on Assignment 4

Prevention of Damage Resulting from Brine Drippings on Track and Structures

Collaborating with Committee 15, and Mechanical Division, AAR

W. E. Cornell (chairman, subcommittee), L. L. Adams, H. S. Ashley, T. H. Beebe, Blair Blowers, J. C. Brennan, H. F. Busch, F. W. Creedle, D. C. Hastings, C. C. Herrick, E. R. Murphy, J. S. Parsons, S. H. Poore.

This is a progress report, submitted as information.

Laboratory work in connection with the study of inhibition of corrosion due to brine drippings was continued during the past year at the AAR Research Center, under the general direction of G. M. Magee, director of engineering research, Engineering Division, and under the immediate supervision of S. K. Coburn, chemical engineer, Engineering Division. Earlier work, described previously (see Proceedings, Vol. 55, 1954, page 1084), indicated the satisfactory development of means for the precleaning of test specimens, their exposure to an atmosphere of exaggerated corrosive conditions for 30 days, and the cleaning and evaluation of the corroded specimen. Of primary importance was the necessity for determining whether the accelerated corrosion of metal coupons would lead to valid conclusions after 30 days' exposure. In addition it was necessary that the corrosion produced in the laboratory specimens be similar to that found in corroded rail.

To learn whether 30 days' exposure was sufficient, medium carbon-steel coupons were carried through the corrosion cycle for 30, 60 and 90 days, respectively. The coupons were divided into groups of four and immersed in five percent brine solution and five percent brine solution containing an inhibitor. One of the inhibitors, identified as the standard inhibitor, is an efficient though toxic material. Weight loss data show that, in the system presently used, corrosion continues unabated for 90 days, while accelerating in rate in some instances during the last 30 days. The data are summarized and shown graphically in Fig. 1.

It is interesting to note the relatively constant rate of corrosion of coupons immersed in brine containing the standard inhibitor and the sodium polyphos-calcium chloride

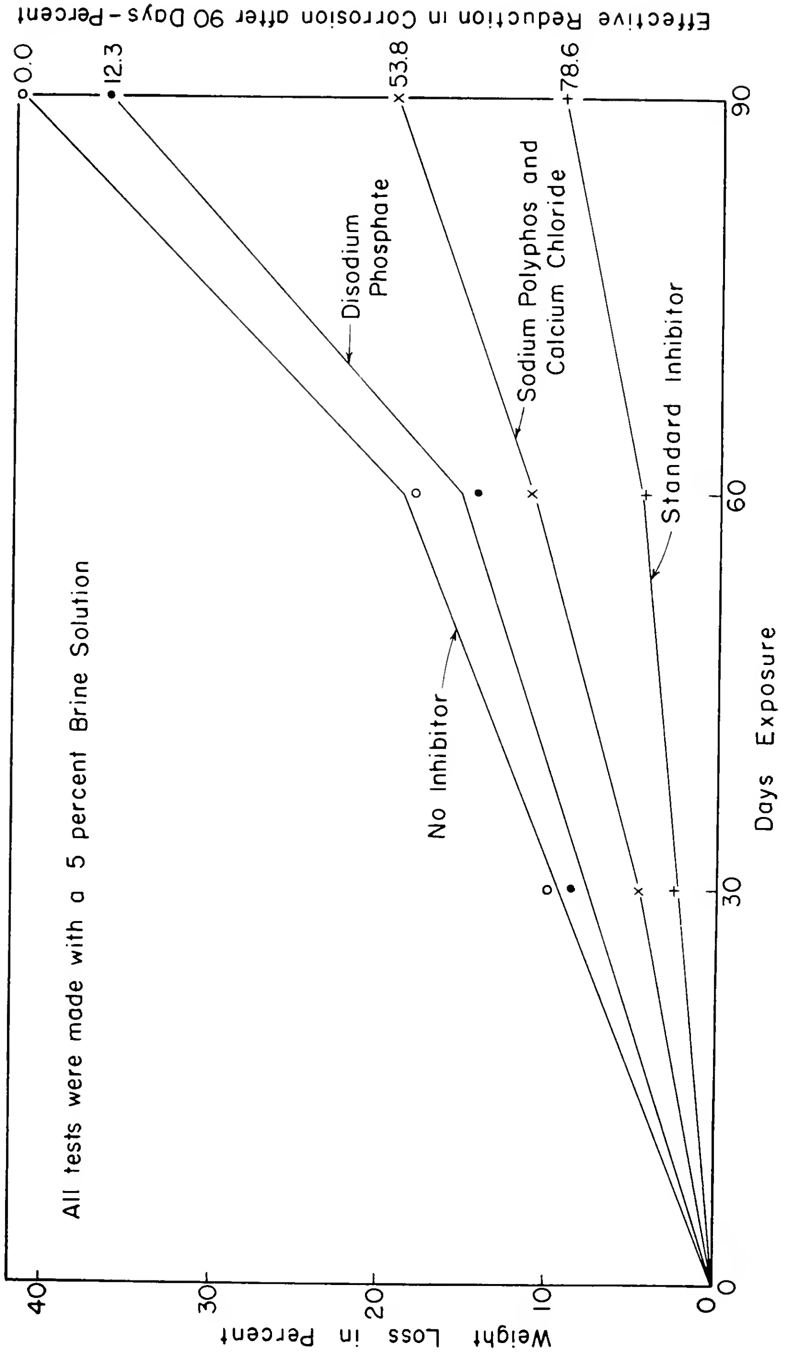


Fig. 1. Corrosion Data for Three Sets of Coupons Exposed for 30, 60, and 90 Days Respectively

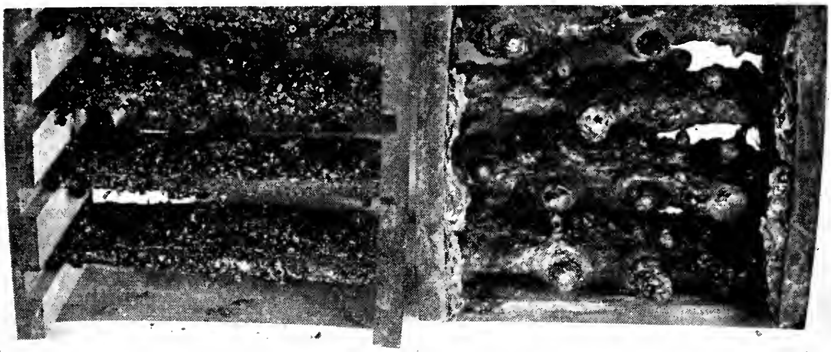


Fig. 2—Specimens exposed to inhibited and uninhibited 5 percent brine solutions for 90 days.

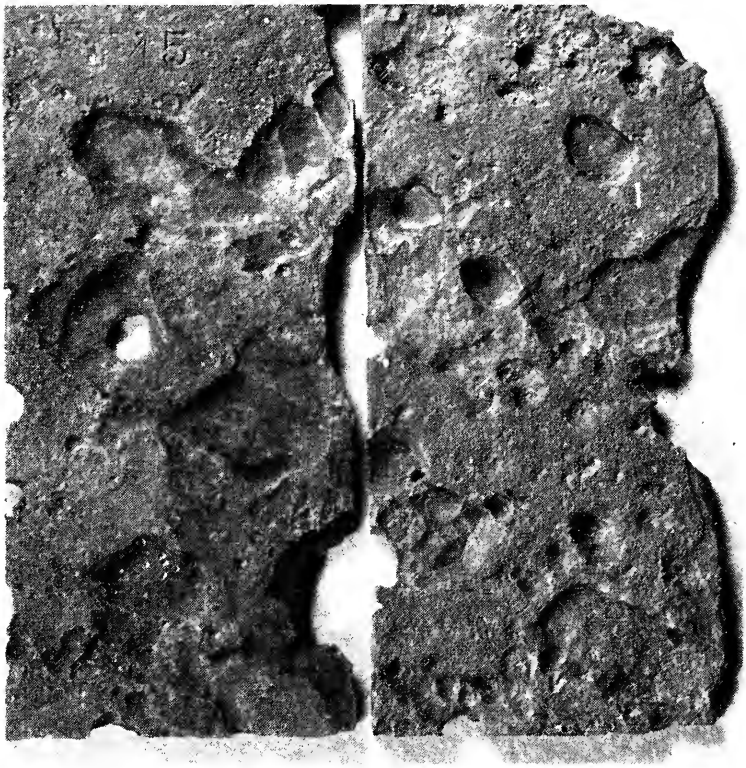
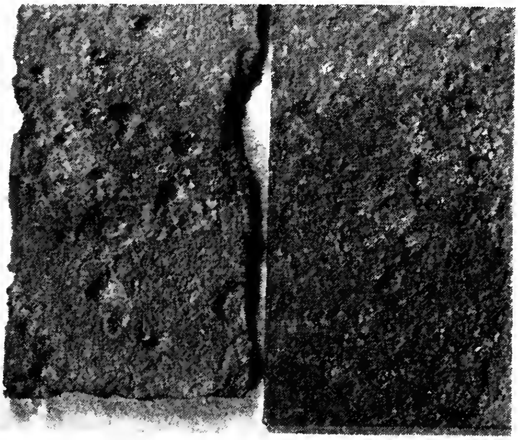


Fig. 3—Specimens after removal of rust following exposure in uninhibited brine solution for 90 days.

Sodium Polyphos Calcium Chloride — Standard Inhibitor

Fig. 4—Inhibited specimens after removal of rust following corrosion cycle.



Disodium Phosphate — Standard Inhibitor

Fig. 5—Example of poorly inhibited specimen.

inhibitor. This action is in contrast to the sharp acceleration of the corrosion rate for an uninhibited brine solution and a relatively inefficient inhibitor (disodium phosphate). An examination of Fig. 2 indicates the degree of corrosion resulting from the presence and absence of an inhibitor. Note particularly the large bulky projections of rust called tubercles. These same areas in picked specimens are the site of the deepest pits and the maximum corrosion.

The question of whether the type of corrosion produced is similar to that found in track is answered by examining the coupons pictured in Figs. 3, 4 and 5. Observe the deep pits and the evidence of perforation in Fig. 3, both of which are characteristic of brine corrosion. This phenomenon is in contrast to the corrosion evidenced by coupons immersed in inhibited brine solutions, illustrated in Fig. 4. Note the absence of large deep pits. The presence of an inhibitor tends to make the brine corrosion more general and less intense. In Fig. 5 there is shown the behavior of an ineffective inhibitor. The pitting action approaches that of uninhibited brine. The results of these continuing studies help to define the optimum time interval necessary to conduct a reliable inhibitor evaluation test. Additional inhibitors are being investigated in this manner.

Along with our laboratory investigation we have been able to follow closely the work being done by the Canadian National Railway. They have been using the sodium polyphos-calcium chloride combination for approximately one year. As a result of single ownership and operation, they are in a unique position to control the addition and provide a service check on the effectiveness of the inhibitor. The information they derive will prove useful in the interpretation of our laboratory results, since we do not have a similarly controlled operation in the United States.

Report on Assignment 5

Design of Tie Plates

Collaborating with Committees 3 and 4

M. D. Carothers (chairman, subcommittee), L. L. Adams, W. G. Arn, E. W. Caruthers, W. E. Cornell, Blair Blowers, C. A. Colpitts, F. W. Creedle, J. W. Fulmer, A. E. Haywood, J. P. Hiltz, J. W. Hopkins, C. N. King, J. A. Reed, R. D. Simpson, R. C. Slocomb, R. H. Timmins, M. J. Zeeman.

This report, submitted as information, gives the results of the service tests being conducted with the original seven, and two additional, designs of tie plates in track with 112-lb rail on the Illinois Central Railroad.

TESTS ON THE ILLINOIS CENTRAL RAILROAD

Introduction

These service test installations are located in the southward main of the IC near Curve and Henning, Tenn., and were last reported in the Proceedings, Vol. 54, 1953, page 1037. Seven designs of tie plates for a rail base width of 5½ in were placed on new creosoted oak and pine ties in 28 panels of track, October 1944, and were equally divided between tangent track and a 4-deg curve. The curve is maintained with approximately 4 in elevation and carries some freight trains which operate well below the balanced speed of the curve. On the tangent test sections near Henning, all classes of trains operate near their maximum authorized speeds. Passenger trains are hauled by diesel power, and freight trains are hauled by steam power of the 2–8–4 and 2–8–2 types.

In January 1947, 3½ track panels of 12-in tie plates, with ⅞-in eccentricity, were placed on new creosoted oak ties in both rails of the test curve. When it was necessary to re-adze the pine ties under the inner rail of the 4-deg curve, July 1950, the 7 original tie plate designs were replaced with 15-in tie plates (1¼ in eccentricity). These supplemental tests were for the purpose of studying 2 special designs of tie plates to determine their capacity for equalizing tie abrasion at the plate ends and thus reducing gage widening attributed to the outward canting of the rails. Unfortunately, because of the deterioration of the pine ties under the inner rail by 1950, the full benefit expected from the 15-in tie plates was not realized.

This year the IC decided to relay both rails of the 4-deg curve with used full head 112-lb rail. The pine ties on the curve had deteriorated to such an extent that it was decided to discontinue those 7 test panels so the IC could replace them with hardwood ties and restore the track to a normal maintenance condition. Softwood ties are not generally used by the IC on curves as sharp as 4 deg, but they very kindly permitted the installation to secure accelerated tie abrasion. The test measurements were taken on the curve in April 1954, after the test track had carried 176 million gross tons of traffic, and on the tangent test, June 1954, after 178 million gross tons.

Tie Plate Penetration

A summary of the tie abrasion measurements for all tie plate designs, except the 12-in length, is given in Table 1. The data for the test curve cover a period of 9½ years, except for the 15-in tie plates. During the last service period there was no acceleration of the rate of wear of the hardwood ties under either rail of the curve. Tie abrasion accelerated appreciably in the outer rail of the softwood ties and moderately in the remaining tangent test panels, all having softwood ties.

The 13-in tie plate has continued to show more reduction in plate cutting compared with the five 11-in designs (⅜ in eccentricity) than would be expected from the inverse ratio of the plate lengths. For the average of both rails in the oak sections and the outer rail with pine ties, the longer plate reduced the plate cutting 21 percent, compared with the computed value of 15 percent. Using the average for the same 11-in plates, the plate cutting on the oak ties in the curve was 3 percent greater under the inner rail than the outer one. This figure appears to be too small, and probably has been distorted by moving the plates in the outer rail for re-gaging without re-adzing sufficiently to provide good seating of the plates. On the outer rail the 11-in plates abraded the pine ties 40 percent more than on the hardwood ties. This percentage in the last report was only 24, which indicates an acceleration of the deterioration of the softwood ties under the plates of the outer rail. Plate cutting for the 11-in plates in the outer rail of the curve with pine ties was 17 percent greater than the average of the softwood ties in tangent track. This small difference can be partially explained by the fact that there was a larger percentage of the pine ties in tangent that were failing by crushing under the plates. The 8½-in by 11-in 3170 plate, with ½ in eccentricity, showed some benefit in equalizing the cutting at the plate ends in the outer rail on the softwood ties. The abrasion by this plate in tangent track was lower than for the other 11-in plates. Some of this advantage was probably due to the fact that the pine ties in that section were in better condition and had less crushing under the plates than in the other tangent test sections.

The centroid of the tie plate pressure, as computed from the tie abrasion measurements for the 5 panels of 11-in plates with ⅜ in eccentricity, was as follows: Outer rail for both oak and pine ties, 0.8 in; inner rail for oak ties only, 1.24 in. These values, all being computed from the center line of the rail base toward the field side of the rail, compare with 0.5 in and 1.4 in, as determined from the measurements made with the dynamometer tie plates in 1946. Because the center of pressure has moved further out for the outer rail, it is possible that more traffic in recent years has traversed the curve above the balanced speed of 39 mph.

Because of the increasing number of tangent pine ties becoming crushed in the tie plate area, that portion of the test may be discontinued in a year or two. Some of the crushed ties have been omitted from the tie abrasion measurements in recent years in

TABLE 1. SERVICE TEST OF MECHANICAL WEAR OF TIES WITH EIGHT DESIGNS OF TIE PLATES FOR 112-RE RAIL IN THE SOUTHBOUND MAIN OF THE ILLINOIS CENTRAL SYSTEM NEAR CURVE AND HENNING, TENN.

Tie Plate Design No.	Tie Plate Dimensions in	Rail Seat	Tie Plate Penetration in 0.001 in						
			Inner or West Rail			Outer or East Rail			Average Both Rails
			Field End	Gage End	Avg.	Gage End	Field End	Avg.	
4^{o} Curve - Creo. Oak Ties Oct. 1944 to April 1954 - 176 million gross tons									
419	7 3/4 x 13 x 27/32	Flat	395	206	300	241	374	308	304
419-Z	7 3/4 x 11 x 27/32	Flat	522	245	384	278	465	372	378
419-Y	7 3/4 x 11 x 11/16	Flat	607	217	412	275	526	400	406
419-X	7 3/4 x 11 x 9/16	Flat	603	252	428	349	526	437	432
366	8 x 11 x 23/32	Beveled	584	183	383	230	437	334	358
400	7 3/4 x 11 x 23/32	Rolled Circular	549	139	344	290	397	344	344
3170	8 1/2 x 11 x 3/4	Pressed Circular	509	241	375	216	478	347	361
4^{o} Curve - Creo. Pine Ties Oct. 1944 to April 1954 - 176 million gross tons									
419	7 3/4 x 13 x 27/32	Flat	See data for 15" plates below			337	495	416	
419-Z	7 3/4 x 11 x 27/32	Flat				425	676	550	
419-Y	7 3/4 x 11 x 11/16	Flat				450	657	554	
419-X	7 3/4 x 11 x 9/16	Flat				496	607	552	
366	8 x 11 x 23/32	Beveled				318	597	458	
400	7 3/4 x 11 x 23/32	Rolled Circular				402	626	514	
3170	8 1/2 x 11 x 3/4	Pressed Circular				481	474	478	
Tangent - Creo. Pine Ties Oct. 1944 to June 1954 - 178 million gross tons									
419-Y	7 3/4 x 11 x 11/16	Flat	356	582	469	460	341	401	435
419-X	7 3/4 x 11 x 9/16	Flat	407	574	490	508	352	430	460
366	8 x 11 x 23/32	Beveled	374	611	492	517	366	442	467
400	7 3/4 x 11 x 23/32	Rolled Circular	330	492	411	527	387	457	434
3170	8 1/2 x 11 x 3/4	Pressed Circular	276	468	372	426	256	341	357
Inner Rail of 4^{o} Curve - Creo. Pine Ties June 1952 to April 1954 - 32 million gross tons 8 x 15 Tie plates, 1 1/4-in Eccentricity, Flat Rail Seat									
Sec. No.	Description of Hold-Down Fastenings		Field End	Gage End	Avg.	Gage End	Field End	Avg.	
15-1	3 Cut Line Spikes & 2 Racor Studs		142	54	98	See data for Creo. pine ties above			
15-2	3 Cut Line Spikes & 2 Lock Spikes		125	55	90				
15-3	3 Cut Line Spikes & 2 Cut Anchor Spikes		159	88	123				

All tie plates have flat bottom and 3/8-in eccentricity except pattern No. 3170 which has pressed circular bottom and 1/2-in eccentricity, and the 15-in plates have 1 1/4-in eccentricity.

order to endeavor to keep equal service conditions in the five test panels. It is proposed to continue the remaining test panels on the curve until it is necessary to re-adze and set up the inner rail on the oak ties. The curve now has 132 RE rail laid on the adjoining tangents and is scheduled for relay as soon as the AAR–IC tests are discontinued. Nothing would be gained by further delaying the improvement program of the IC after the ties are readzed, other than determining the effects of corrosion and fatigue on the tie plates.

This information can be developed from the tie plate design service tests on the Southern Railway System near Chattanooga, Tenn.

Data for the 15-in tie plates with 1¼ in eccentricity are given at the bottom of Table 1. The results cover only the last service period as the previous period was used for seating of the tie plates. Because of the soft tie condition under the plates, the special hold-down fastenings were not as effective in reducing plate cutting as had been determined from other tests which were made with new ties. The soft timber also detracted from the effectiveness in equalizing the tie abrasion at the ends of the tie plates. The ratio of the field to gage depth of plate cutting ranged from 1.81 to 2.63, averaging 2.24. This compares with an expected ratio of 1.13, which was computed from the dimensions of the plate and the average position of the tie plate centroid, as determined with the dynamometer tie plates in 1946. The ratio of 2.24 was an improvement over 3.72 for the 13-in plates for the test period ended in 1950 on the inner rail of the pine ties. The results of the test with the 15-in tie plates have been distorted by crushing of the soft ties and should not be used for judging the merits of the tie plate design or the special hold-down fastenings. It is proposed to install the 15-in plates on new ties at another location.

Tie Plate Bending

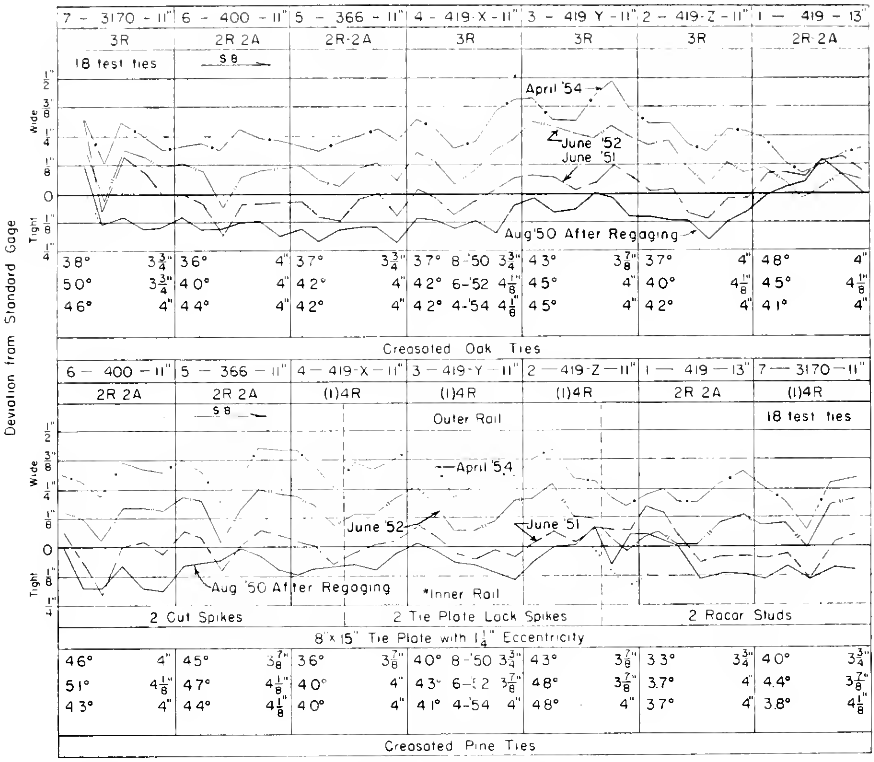
When the test plates were removed from the outer rail of the pine ties in June 1954, one of the 419–X plates was found to be bent upward 0.06 in as measured at the field end of the plate from a straight edge resting on the longitudinal center line of the plate. Four of the same pattern of tie plates were found bent when removed from the inner rail of the curve in 1950. The 419–X plate is ⅛ in thinner than the plate shown in AREA Plan 4. The tie plate bending measurements taken in 1954 on the other plates did not indicate any had become permanently bent. So far, the results from these tests indicate that the thickness of $\frac{11}{16}$ in at the outer shoulder of the 11-in plate shown in Plan 4 is not more than justified for a service life of 20 years, with normal corrosion.

Gage of Track

A record of the track gage of the 4-deg curve from 1950, after regaging and relaying the inner rail, to April 1954, before relaying both rails, is shown in Fig. 1. Since regaging the curve in 1950, the average gage widening of the 7 test panels was the same for the oak and pine ties. The 15-in tie plates, particularly in the panels with 11-in tie plates on pine ties in the outer rail, were benficial in keeping the gage from widening more than in the corresponding panels with oak ties. However, all of the pine ties had at least 4 spikes per plate, while in the oak tie sections, four panels had only 3 cut spikes per plate. Fig. 2 includes the record of the track gage for the 5 panels remaining in the test on tangent track. The gage irregularity has increased moderately in some panels and reduced slightly in others. In all test panels on tangent, the plate cutting is greater at the gage end of the plates. This should cause tightening of the gage of track, but apparently the outward movement of the plates on the ties has offset that tendency, except for parts of panels 5 and 7.

Tests of 12-In Tie Plates with ⅞ In Eccentricity

These plates were obtained by shearing 1 in off the 13-in 419 plates at the gage end. Because the compromise eccentricity of the tie plate loads for the 4-deg curve was found to be about 1 in (as determined from tests made with the dynamometer tie plates), the 12-in plates were placed in both rails on new creosoted oak ties to determine if this arrangement would be effective in reducing gage widening caused by unequal plate cutting.



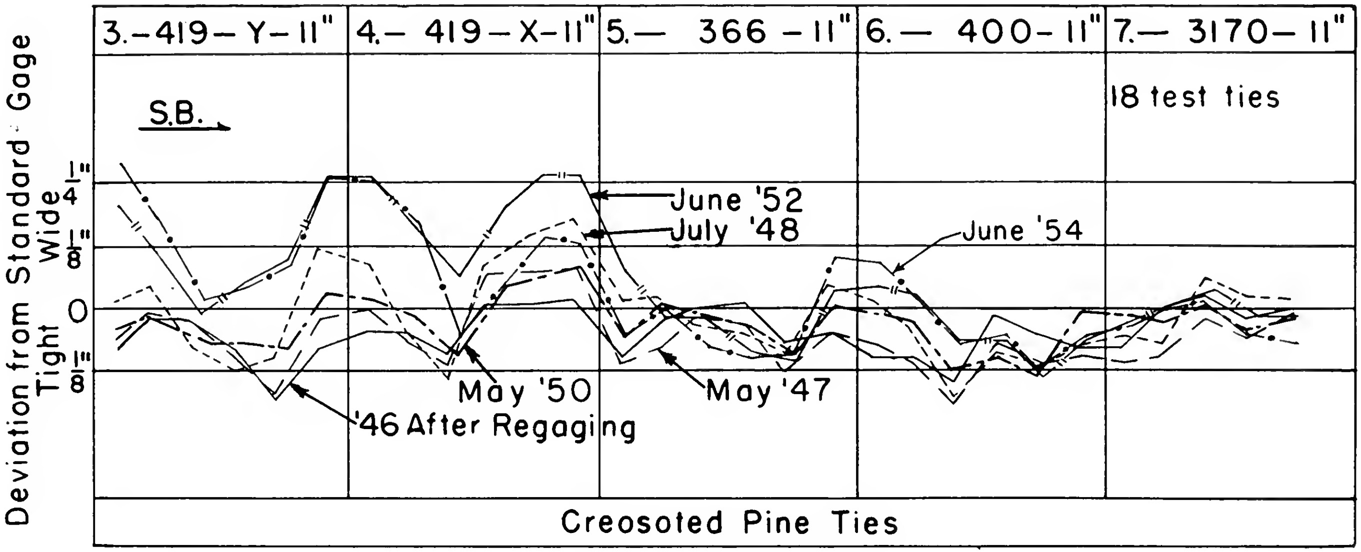
Panels divide at joints in outer rail. 2R, 3R, or 4R indicate the number of line spikes per tie plate; 2A the number of anchor spikes per tie plate (1) The fourth line spike was driven September 1, 1948 * Rail was relaid, all pine ties mechanically adzed, and 15-in plates with 1-1/4-in. eccentricity were installed July 25, 1950. ········ Regaged August 1951

Fig. 1 Gage, curvature and elevation of each panel of test track on the 4-deg curve, Mile L-333, I C R R

From May 1947, when the initial penetration readings were taken, to April 1954, the test curve carried 123 million gross tons of traffic. The total plate cutting in inches is as follows:

Inner Rail			*Outer Rail*			*Avg. Both Rails*
Field End	*Gage End*	*Avg.*	*Gage End*	*Field End*	*Avg.*	
0.290	0.104	0.197	0.225	0.253	0.239	0.218

The average of 0.218 in for both rails compares fairly well with the value of 0.230 in for the 13-in plates on oak ties after 143 million gross tons of traffic. The tie abrasion of the outer rail was almost equalized. The eccentricity of the tie plate was not sufficient to equalize the cutting on the inner rail. However, the actual ratio of depth of cutting, field end to gage end, was 2.79 for the inner rail, compared with the expected value of 1.7. It is possible that the tie plates may not have assumed a normal seating when the



Each tie plate has 2 rail and no anchor spikes. Panels divide at joints in west rail. Each panel of test track has 23 ties except panel No. 7 which has only 18 test ties. All panels have 39 ft. rails.

Fig. 2. Gage of Each Panel of Test Track on Tangent at Henning, Tenn., I.C.R.R.

initial readings were taken. During the last service period the rate of plate cutting of the 12-in plates increased moderately with respect to the traffic tonnage.

Fig. 3 is included to give information on the gage widening in 3½ track panels of the 12-in plates and adjoining panels not in this test. The widest gage in panel 11 may have been influenced by the sharp curvature prevailing in that panel since regaging. This portion of the curve was also relaid on both sides in June 1954.

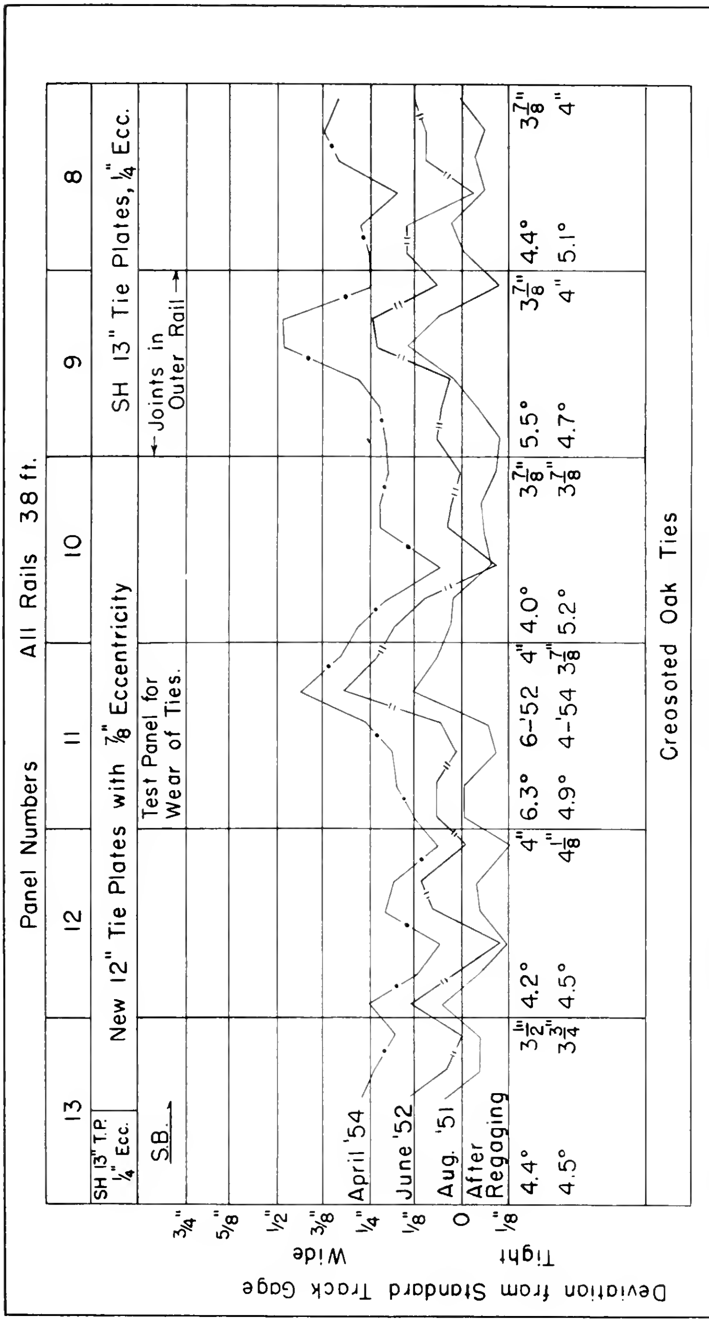
Analysis of Gage Widening as to Causes

It will be of interest to investigate the causes of gage widening in the 14 original test panels of the 4-deg curve for the 9½-year test period. The total gage widening for this period will be subdivided as to (1) unequal plate cutting, (2) wear on the outer rail, and (3) the remainder, or that portion which is attributed to horizontal movement of tie plates on the ties. Table 2 gives a summary of the gage widening for the 13-in tie plates and the 5-panels of 11-in plates having ⅜ in eccentricity. For both lengths of tie plates, the total gage widening was about 0.3 in greater on the pine ties. Most of this occurred prior to installation of the 15-in plates. It will be observed for both kinds of ties, the excess gage widening of the 11-in plates over that of the 13-in plates was in the gage widening attributed to unequal plate cutting, which resulted in both rails canting outward. For each kind of tie, the gage widening attributed to plate movement was about the same for the 11-in and 13-in plates. These values were higher in magnitude for the softwood ties. For each length of plate, percentages for each category are shown in the table. Gage widening from unequal plate cutting ranged from 20 to 34 percent, and plate movement ranged from 35 to 48 percent. The combined gage widening resulting from the two last mentioned causes varied from 61 to 76 percent, or about ⅔ of the total gage widening. It has been found from other tests that special hold-down fastenings reduced plate cutting about 50 percent, as well as one-half of the gage widening caused by unequal plate cutting. Also, some types of hold-down fastenings should eliminate 80 percent of the plate movement. On this basis, effective anchor spikes should reduce the gage widening approximately 50 percent, including rail wear, or about 70 percent excluding rail wear.

The corresponding values for the total service period of the 12-in plates with ⅞ in eccentricity are as follows: Total gage widening 0.58 in, including 0.12 in for unequal plate cutting, 0.28 in for rail wear, and 0.18 in for plate movement on the oak ties. The respective percentages are 100, 21, 48 and 31. The 12-in plates carried a total of 123 million gross tons of traffic, compared with the corresponding value of 176 million for the other test panels on the curve. As to gage widening resulting from unequal plate cutting, the 12-in plates, percentagewise, were about equal to the 13-in plates on the oak ties. The shorter plate with a larger eccentricity has performed almost as well as the longer plate with a smaller eccentricity, but the former should have equalized the plate cutting better, particularly for the inner rail.

Report on the Examination of a Creosoted Pine Tie Removed from the 4-deg Test Curve

In June 1954, when the creosoted pine ties in the 4-deg curve were replaced with hardwood ties, one of the softwood ties was selected at random for making a laboratory examination of its condition. A 2-ft length for each tie plate area was furnished to the research laboratory of the Timber Engineering Company for an analysis. The specimen tie had been in service from October 1944 to June 1954. During the entire test period the outer rail had one of the 11-in 419-X tie plates. The same design of tie plate was used on the inner rail until July 1950, at which time the 11-in plate was replaced with



Tie Plates of 12" Length have 7/8" eccentricity, and 3 line and 1 anchor spikes (On new ties).
Tie Plates of 13" Length have 1/4" eccentricity, and 2 line and 2 anchor spikes (On old ties).

Fig. 3. Gage, Curvature, and Elevation of 4° Curve with Tie Plates of Two Eccentricities, Mile L-333, I C R R.

TABLE 2. ANALYSIS OF THE CAUSES FOR GAGE WIDENING ON THE 4° CURVE. ILLINOIS CENTRAL RR, CURVE, TENN.

(Test Period: October 1944 to April 1954)

No. of Panels and Length of Plates	Test Periods	Total Gage Widening	Unequal Plate Cutting			Rail Wear at Gage Level	Horizontal Plate Movement
			Low Rl.	High Rl.	Total		
		in.	in.	in.	in.	in.	in.
			Creosoted Oak Ties				
One panel of 13-in tie plates	Oct.-1944 May-1950	0.53	0.03	0.03	0.06	0.19	0.28
	May-1950 April-1954	0.27	0.07	0.03	0.10	0.12	0.05
Total	1944-1954 (Percent)	0.80 (100)	0.10	0.06	0.16 (20)	0.31 (39)	0.33 (41)
Five panels of 11-in tie plates	Oct.-1944 May-1950	0.58	0.10	0.04	0.14	0.19	0.25
	May-1950 April-1954	0.40	0.12	0.07	0.19	0.12	0.09
Total	1944-1954 (Percent)	0.98 (100)	0.22	0.11	0.33 (34)	0.31 (31)	0.34 (35)
			Creosoted Pine Ties				
One panel of 13-in tie plates	Oct.-1944 May-1950	0.76	0.17	0.03	0.20	0.19	0.37
	May-1950 April-1954	0.37	*0.07	0.01	0.08	0.12	0.17
Total	1944-1954 (Percent)	1.13 (100)	0.24	0.04	0.28 (25)	0.31 (27)	0.54 (48)
Five panels of 11-in tie plates	Oct.-1944 May-1950	0.87	0.28	0.03	0.31	0.19	0.37
	May-1950 April-1954	0.41	*0.07	0.03	0.10	0.12	0.19
Total	1944-1954 (Percent)	1.28 (100)	0.35	0.06	0.41 (32)	0.31 (24)	0.56 (44)

*15-in tie plates with 1 1/4 in eccentricity were installed in the low rail only, July 1950. All other tie plates included in this analysis have 3/8 in eccentricity. The curve was not provided with rail and flange lubrication.

an 8-in by 15-in tie plate having an eccentricity of 1¼ in, after the ties had been mechanically adzed on the low side. The tie specimen was adzed about 1 in deep.

The following report is a condensation from the information furnished by T. G. Gill, Senior Technologist, TECO.

The underplate areas of the tie were in such poor condition that it was not possible to cut microtome sections for a microscopic examination. The examination was, therefore, made with a 10x lens. The depth of plate cutting was 0.34 in and 0.27 in for the field and gage ends of the 15-in plate, respectively. Corresponding depths for the 11-in plate on the outer rail were 0.85 in and 0.56 in, respectively.

The inner rail underplate area had severe ring separations (shakes) resulting from failure of the weaker springwood rings and causing the summerwood rings to shell off. There was one ring separation ¼ in wide that extended for one-half the depth of tie and was packed with dirt and sand. Due to shakes and splits, the tie was not acting as a unit under the plate. At the center of the tie plate area the wood was crushed to a depth of one inch. Because of the ring separations, the top of the tie had become 1-in wider than the bottom, or 9¼ in vs 8¼ in wide (Fig. 4). In the areas of greatest damage, the springwood (the early growth of the annual ring containing thin walled cells) was practically pulverized. Fig. 4 also shows a view of the 2-ft tie specimen and 4 sections throughout the plate area. The tie had been adzed about 1 in deep under the low rail in 1950, and had been damaged so severely that full benefit of the special 15-in tie plate was not obtained.

The outer rail underplate area (Fig. 5) had only $\frac{11}{16}$ in crushing due to ring separation near the center. This end of the tie had not been mechanically re-adzed. This area had deformations similar to the inner rail area, but the rings had not become separated to the same extent. The wood was acting as a unit under the outer rail tie plate. Two of the cross sectional views in Fig. 5 show the extent of crushing.

The tie was cut from second growth southern pine and had a small heart as indicated in Figs. 4 and 5. Many of this kind of tie have a tendency to develop ring separations. The ring separations reduce the strength of the wood.

An examination of the underplate areas was made for decay. The creosote had penetrated to approximately 5 growth rings from the center and no decay was detected in the specimens.

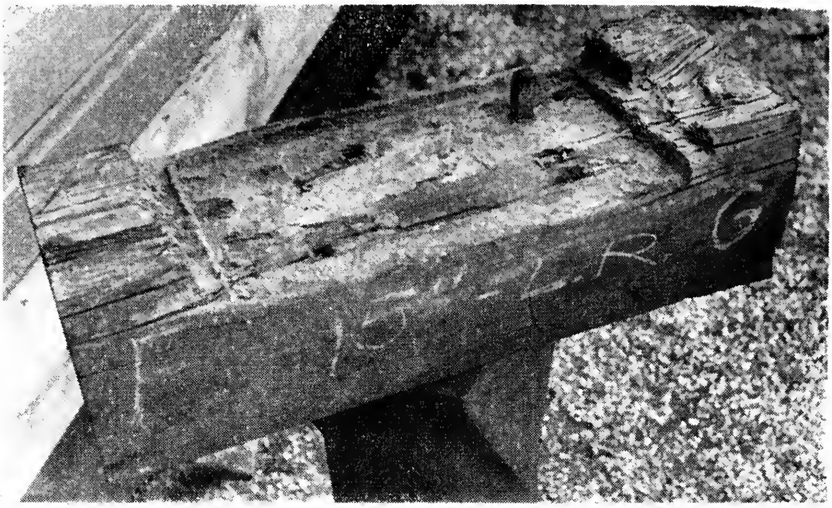
Because of the weakened condition of the ties in the inner rail plate area, the 15-in plates did not reduce the plate cutting or canting outward of the inner rail as much as was expected. It is contemplated to re-install the 15-in plates at another location, using new ties.

Summary

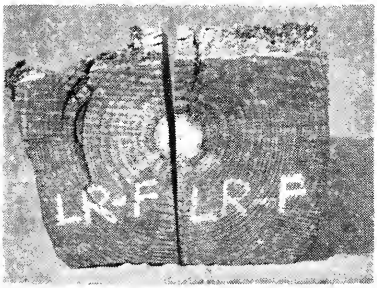
The 13-in tie plates on the curve have been effective in reducing tie abrasion below that of the 11-in plates. The amount of plate cutting of the six 11-in designs has not been significantly influenced by the several design features, except that the 3170 plate, with approximately 10 percent more area than the 7¾-in by 11-in plates, had less abrasion on the softwood ties in tangent track. This can be partially attributed to the ties being in better condition. The ⅞ in eccentricity plates on the test curve have shown only moderate benefits for reducing gage widening. The 1¼-in eccentricity tie plates were beneficial in holding the gage on the softwood ties, but fell below expectations because of the damage to the ties prior to their installation. Only a few of the 419-X tie plates were found to be permanently bent. However, it cannot be said that the present standard AREA 11-in plates are too thick.

A study of the causes of gage widening on the test curve, exclusive of rail wear, indicated that the major influence was the horizontal tie plate movement on the ties, regardless of the size of the plate. Special hold-down fastenings to replace the common cut spikes have shown a marked superiority for holding gage in other tests conducted by the AAR.

This test has shown the inadequacy of the 11-in plates for use on softwood ties in the test curve. In both rails of the curve, the softwood ties in the underplate area were over-



Specimen as Cut from Creosoted Pine Tie

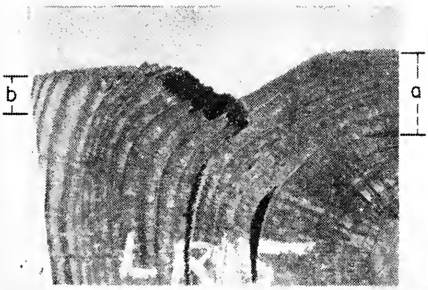


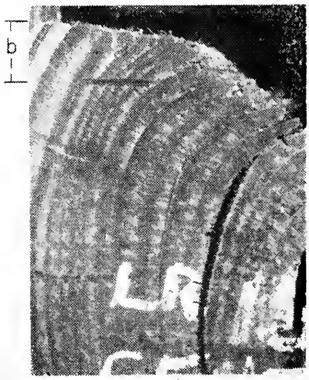
Section at Field End of Tie Plate

Section at Gage End of Tie Plate

a = Depth of ring failure, parallel to surface

b = Depth of ring failure, angled 45°±





Sections near Center of Tie Plate Area

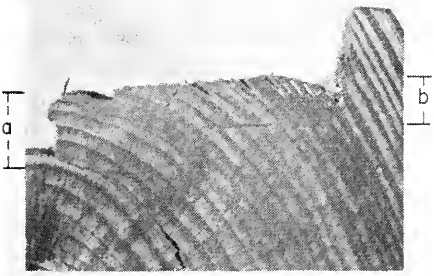
Fig. 4. Condition of the Inner Rail Tie Plate Area of a Creosoted Pine Tie in the 4-deg Curve

Specimen as Cut from Creosoted Pine Tie

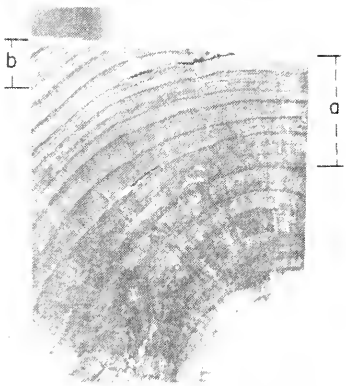
Section at Field End of Tie Plate

Section at Gage End of Tie Plate

a = Depth of ring failure, parallel to surface
b = Depth of ring failure, angled 45°+



Section at Field End of Tie Plate



Section near Center of Tie Plate Area

Fig. 5. Condition of the Outer Rail Tie Plate Area of a Creosoted Pine Tie in the [illegible]-deg Curve

stressed and the wood was failing because of ring separation and some splitting. Several of the pine ties in tangent track are failing by crushing under the tie plates. All of the remaining ties have 11-in tie plates, and it appears that their expectancy will not exceed an average of 15 years. This is an entirely too short tie life, and it can be concluded that the 11-in tie plates are too small for economical use on pine ties in tangent track for the service conditions that prevailed.

Final conclusions should be deferred until the test is completed. However, the results so far have indicated that there is no cause for changing the design of the 11-in and 13-in AREA tie plates, Plans 4 and 7.

Acknowledgement

The Association is indebted to the Illinois Central for the fine cooperation and assistance rendered in conducting the service tests.

Report on Assignment 6

Hold-Down Fastenings for Tie Plates, Including Pads Under Plates; Their Effect on Tie Wear

Collaborating with Committee 3

Blair Blowers (chairman, subcommittee), L. L. Adams, H. S. Ashley, F. J. Bishop, M. C. Bitner, J. C. Brennan, T. F. Burris, M. D. Carothers, W. E. Cornell, H. B. Christianson, C. A. Colpitts, E. D. Cowlin, P. H. Croft, H. F. Fifield, R. G. Garland, V. C. Hanna, J. P. Hiltz, J. W. Hopkins, A. F. Huber, T. R. Klingel, M. P. Oviatt, J. M. Rankin, J. A. Reed, M. K. Ruppert, T. R. Snodgrass, R. E. Tew, Troy West, M. J. Zeeman.

This report, offered as information, covers the service test installations of hold-down fastenings, tie pads, etc., on the Louisville & Nashville Railroad.

SERVICE TESTS ON THE LOUISVILLE & NASHVILLE RAILROAD

Introduction

The principal purpose of this investigation is to develop information for determining the effectiveness and economy of several types of hold-down fastenings, tie pads, etc., for increasing the service life of ties by minimizing plate cutting and reducing the frequency of re-gaging and re-adzing curves. These service tests were begun in 1947* in the northward main of the L&N near London and East Bernstadt, Ky. Last year's report was published in the Proceedings, Vol. 55, 1954, pages 721–749. The major portion of the test sections was installed in August 1947, with subsequent additions or changes made generally each year. Figs. 1 and 2 give the location of the test sections and Tables 1 and 2 include a description of the sections.

There were no additions or changes made to the test installations in 1954. Next year, it is anticipated that possibly two makes of tie pads will be added to the test installations.

A general inspection of the installations was made in May 1954, and the tie pads were inspected by removal, July 21, 1954. This report will include the more important results of the visual inspections. Tie abrasion measurements and a discussion of the pads were published last year.

(Text continued on page 841)

* See Proceedings, Vol. 50, 1949, pp. 595–623, for description of the original test sections.

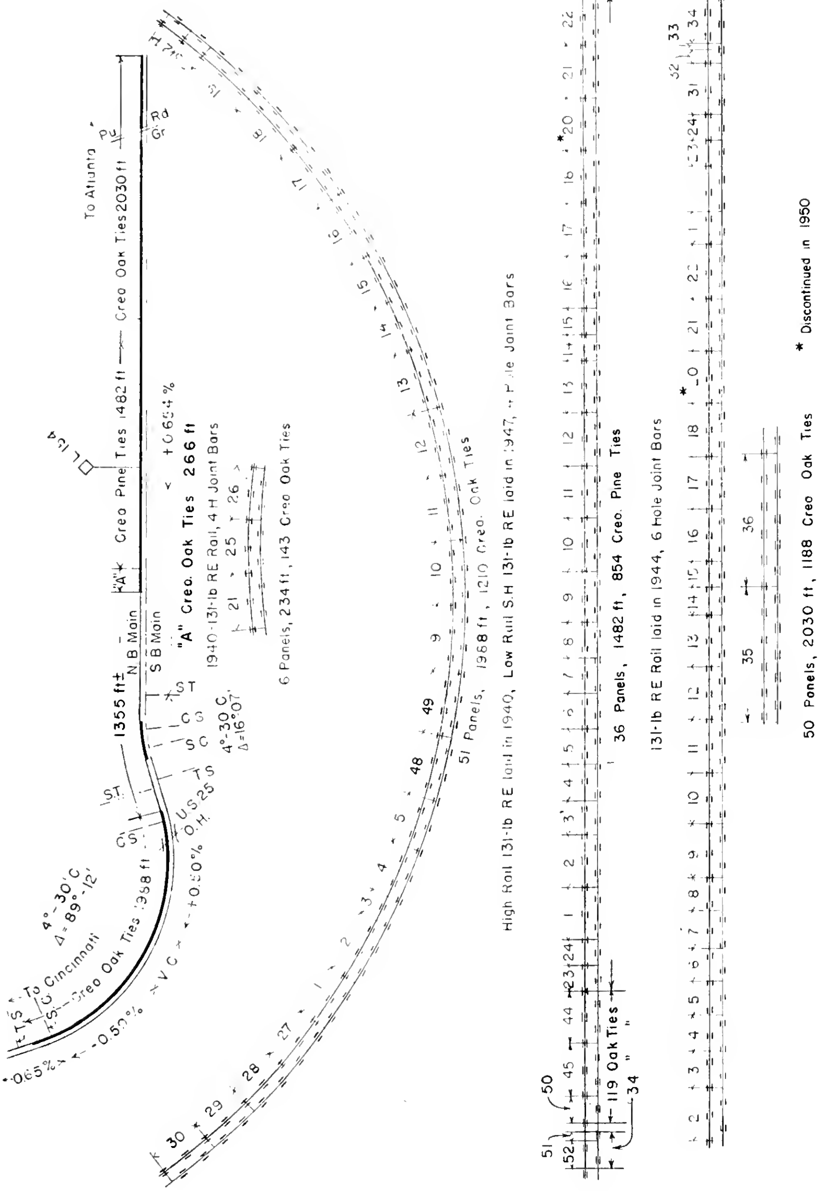


Fig. 1.- Plan of Test Track

TABLE 1. DESCRIPTION OF TEST SECTIONS SHOWN IN FIG. 1

Section No.	No. of Test Ties: Creo. Oak Curve	Creo. Oak Tang.	Pine Tang.	Total	Tie Plate Length in.	Date Built	Number and Type of Hold-Down Fastenings per Tie Plate, Tie Pads and Coatings (131-lb RE Rail)
1							Coatings and adhesives - no anchor spikes - subdivided as follows:
1.1	11	6	12	29	13	9-47	Beckosol No. 40. Hot paddle coat applied to bottom of tie plate
1.2	9	9	9	27	13	9-47	AREA Specification Waterproofing Asphalt applied as in subsection 1.1
1.3	0	4	6	10	13	9-47	CASCO Flexible Cement NT-442 applied to tie plate and tie in the field
1.4	3	3	6	12	13	9-47	NT-442 Cement applied to tie plate as a primer and CASCOPHEN RS-216 applied to tie plate and tie in the field
1.5	9	9	9	27	13	9-47	Same as subsection 1.4 except the tie plates were cemented to the ties before creosoting
1.6	2	0	0	2	13	9-47	Premolded sheet of asphalt, 1/8 in thick, made of regular Bird tie pad coating, designated No. 52
1.7	2	0	0	2	13	9-47	Premolded sheet of asphalt, 1/8 in thick, made of regular Bird tie pad coating modified to further reduce flow, designated No. 53
1.8	2	0	0	2	13	9-47	Same as subsection 1.7, except the asphalt was formed around brass screening, designated No. 54
1.9	2	0	0	2	13	9-47	Same as subsection 1.7, except the asphalt was formed around 1/4 in mesh galvanized screening, designated No. 55
1.10	6	0	0	6	13	8-48	Solvated Sealz Coating. Heavy brush coat applied to tie and tie plate
2	59	47	48	154	13	8-47	No anchor spikes (Rubber line spike cushions were applied to the north 24 ties of each tangent section 12-49)
3	0	31	32	63	13	8-47	1-ply duck pad with asphalt coating (Made by Bird & Son), no anchor spikes
3	(b)24	0	0	24	13	6-52	Bird improved fiber-rubber pads (1-ply duck pads were in service on the same ties from 8-47 to 6-52)
4	(b)27	0	0	27	13	6-52	Bird vinyl pads on N. 27 ties (5-ply duck-felt pads were in service on the same ties from 8-47 to 6-52)
4	0	32	32	64	13	8-47	5-ply Bird duck-felt pads, no anchor spikes
4	20	0	0	20	13	8-48	5-ply Bird duck-burlap pads on the south 20 ties of curve test section (Duck-felt pads in test 8-47 to 8-48), no anchor spikes
5	20	0	0	20	13	8-48	7-ply Bird duck-burlap pads on the north 20 ties of curve test section (Duck-felt pads in test 8-47 to 8-48), no anchor spikes
5	29	31	32	92	13	8-47	7-ply Bird duck-felt pads, no anchor spikes
6	0	32	32	64	13	8-47	2 each of cut spikes for line and Racor Studs for anchors, (Changed from 2 Racor Drive Tight line spikes 12-49)
7*	0	32	32	64	13	8-47	2 each of Racor Drive Tight (Sandberg) line and anchor spikes. (Anchor spikes replaced 11-48)
8*	0	31	32	63	13	8-47	2 each of cut spikes for line and Racor Drive Tight (Sandberg) for anchors. (Anchor spikes replaced 11-48)
9	59	48	48	155	13	8-47	2 each of cut spikes for line and anchors. (Rubber anchor spike cushions were applied to the north 10 pine ties 12-49)
10	59	47	49	155	13	8-47	2 cut spikes for line and 2 round head cut spikes with single coil spring washers for anchors
11	59	47	47	153	13	8-47	2 cut spikes for line and 2 round head Dowel Studs with double coil helical spring washers for anchors
12	57	48	48	153	13	8-47	2 cut spikes for line and 2 Oliver Hold-Down Drive Spikes with double coil helical spring washers for anchors
12	2	0	0	2	13	8-47	2 cut spikes for line and 2 cone neck Oliver Hold-Down Drive Spikes without spring washers for anchors
13	47	47	47	141	13	8-47	2 cut spikes for line and 2 Elastic Spikes of design No. 93 for anchors
13	12	0	0	12	13	8-47	2 cut spikes for line and 2 Tie Plate Lock Spikes for anchors (North 12 ties)
14	47	24	24	95	13	8-47	2 cut spikes for line and 2 - 3/4 in thru bolts with single coil washers for anchors — Applied in the field
15	48	24	24	96	13	9-47	(same as above) Applied in shop under load
16(a)	60	47	48	155	13	8-47	2 cut spikes for line and 2 screw spikes with double coil washers for anchors
17	60	47	47	154	13	8-47	2 AAR spring rail clips and screw spikes for line and anchor spikes on tangent plus 2 cut spikes for line on the curve (PRR standard 14-3/4 in tie plates cut to a 13-in. length with 1/4 in eccentricity)
18	58	48	48	154	13	8-47	No anchor spikes. Erie single shoulder tie plate with diamond bottom and zero eccentricity
19(a)	59	0	0	59	13	8-47	2 cut spikes for line and 2 screw spikes with double coil washers and above Erie RR tie plate
21	0	47	47	94	13	8-47	Fabco tie pads, 1/4 in. thick, uncoated, no anchor spikes
21	47	0	0	47	13	8-48	Fabco tie pads, 1/4 in. thick, uncoated, no anchor spikes

(Continued on next page)

* The supplier of the special fastenings used in sections 7 and 8 requested discontinuance of these sections in 1953.

TABLE 1. (CONCL.) DESCRIPTION OF TEST SECTIONS SHOWN IN FIG. 1

Section No.	No. of Test Ties: Creo. Oak Curve	Creo. Oak Tang.	Pine Tang.	Total	Tie Plate Length in	Date Built	Number and Type of Hold-Down Fastenings per Tie Plate, Tie Pads and Coatings (131-lb RE Rail)
22	0	48	48	96	13	8-47	2 cut spikes for line and 2 Oliver Tie Plate Drive Spikes with single coil spring washers for anchors
23	24	24	23	71	14	9-47	L.& N. standard construction with 2 each of cut spikes for line and anchors
24	24	24	24	72	14	9-47	Same as section 23, except a Rails Co. compression clip was applied to alternate tie plates
25	47	0	0	47	13	8-48	Johns-Manville, uncoated, laminated rubber-asbestos tie pads; 1/8 in thick in north panel, 1/4 in thick in south panel, no anchor spikes
26	49	0	0	49	13	8-48	DL&W D.S. diamond bottom tie plate with 1/2 in eccentricity, 2 cut spikes for line and 1 anchor only
27	48	0	0	48	SH 13	10-48	Burkart fiber pads, no anchor spikes
28	48	0	0	48	SH 13	9-49	Western Felt Works wool felt pads, 1/4 in thick, no anchor spikes
29	48	0	0	48	SH 13	9-49	Bird fiber-rubber pads, 1/4 in thick, coated, no anchor spikes
30	48	0	0	48	SH 11	9-49	Bird 5-ply duck-burlap pads. SH 11 in plates were cut from 13 in. Plan 5B plates, no anchor spikes
31	0	48	0	48	14	8-49	G&H Controls No-Creep rail anchors on alternate tie plates. 2 cut line spikes on unanchored ties, 1 cut line spike and 2 Oliver Tie Plate Drive Spikes for anchors on anchored ties
32	0	12	0	12	14	9-49	Farbertite. Paddle coat applied to adzed surface and bottom of tie plate, no anchor spikes
33	0	5	0	5	14	9-49	Tie plates cemented to ties as in section 1.5 but under ideal conditions, no anchor spikes
34	0	48	0	48	14	9-49	2 cut spikes for line and 2 Tie Plate Lock Spikes for anchors. Asphalt roofing paint brushed on adzed surfaces of south 24 ties
35	0	120	0	120	SH 13	7-50	Coating of Koppers No. 16 Sealing Compound with covering of 1/4 in washed gravel on alternate new ties, 2 each of cut line and anchor spikes
36	0	118	0	118	SH 13	7-50	Coating of Koppers No. 16 Sealing Compound with covering of 1/4 in washed gravel on existing ties, 2 each of cut line and anchor spikes
44	0	48	0	48	12 7/16	11-50	Dayton Rubber Co's. cast steel tie plates with raised rubber insert pads on new ties, 2 each of cut line and anchor spikes
45	0	47	0	47	12 7/16	11-50	Same as section 44 except that existing ties in track were used
48	58	0	0	58	14	8-52	Racor coated tie pads with 2 cut line spikes and 2 Racor studs for anchors
49	60	0	0	60	14	8-52	2 cut spikes for line. 3 Racor studs as anchors on N. 30 ties and 4 on S. 30 ties
50	0	24	0	24	14	7-53	Paddle coat of "Anker Seel" applied to adzed surfaces, 2 each of cut line and anchor spikes
51	0	10	0	10	14	7-53	2 cut spikes for line and 2 creo. hardwood Nordberg pegs for anchors
52	0	24	0	24	14	8-53	Paddle coat of Protek-Tie applied to adzed surfaces, 2 each of cut line and anchor spikes
	1,353	1,341	854	3,546			Totals

Notes: All of the new 13-in tie plates, except as noted above, were of the AREA Plan 5B (Modified) design with flat rail seat. Second hand (SH) 13-in tie plates were of the Plan 5B Design with rolled circular crown. All of the 14-in tie plates placed prior to 1949 were of the AREA Plan 6B design and subsequent installations were of the current design, AREA Plan 12.
All tie plates have flat bottom except as noted above.
In the sections on the two 4-deg 30 min curves where no anchor spikes were provided, 4 cut spikes were used.
(a). In the north half of each portion of the test sections the double coil Helical (experimental) spring washer was used and in the south half the double coil Thackery washer was used.
Prior to 1952, all of the above tie pads were placed without anchor spikes, except in sections 44 and 45. (b). These pads have 2 each of cut line and anchor spikes.
Section 20 with 2 Thompson rail and tie plate clamps has been excluded from this table and discontinued upon request by the sponsor.
Each portion of each test section has an oval tag on the north tie showing the section number, and every tenth tie from the north has a smaller tag showing the tie number.

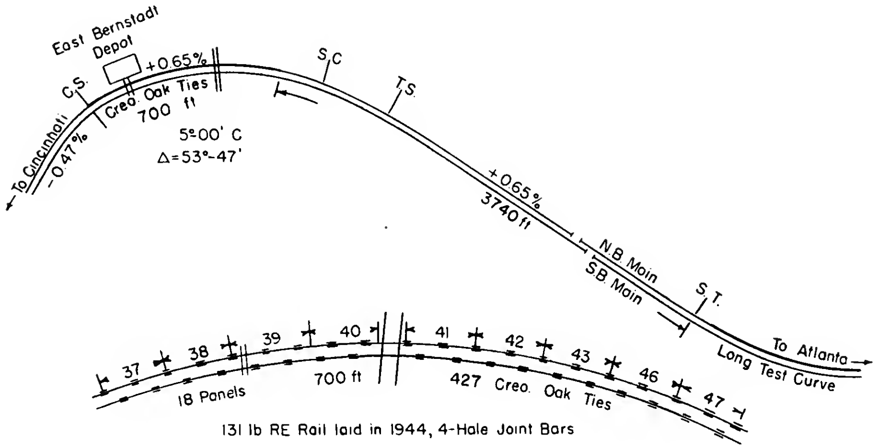


Fig. 2.—Plan of Test Track

TABLE 2. DESCRIPTION OF TEST SECTIONS SHOWN IN FIG. 2.

Section No.	No. of Creo. Oak Ties	Date Built	Number and Type of Hold-Down Fastenings per Tie Plate and Tie Pad AREA Flat Bottom 14-in. Tie Plates, 131-lb. RE Rail
37	48	7-50	2 each of cut spikes for line and anchors
38	48	6-52	Achuff sisal fiber pads, uncoated (Original pads placed 7-50, third set installed 6-52)
39	22	7-50	Johns-Manville rubber-vegetable and asbestos fiber pads, uncoated (North 22 ties)
39	22	11-51	Johns-Manville rubber-comp. pads with coating on the bottom side, replacing original J.M. pads placed 7-50
40	48	7-50	Taylor Fibre Co's. rubber-vulcanized fiber laminated pads
41	23	7-50	Fabco pads, uncoated (North 23 ties)
41	12	7-51	Fabco pads with an oxidized asphalt coating compound on the bottom side. (These pads replaced pads placed in 7-50 with Baker's K-2 cement on the bottom side.)
41	12	7-50	Fabco pads coated on both sides with Baker's S-72 cement (South 12 ties)
42	48	7-50	Dunne Rubber Co's. molded rubber pad, 1/8 in thick, uncoated
43	47	7-50	2 each of cut spikes for line and Racor Studs for anchors
46	24	11-51	Racor rubber-fiber pad, uncoated
46	25	11-51	Racor rubber-fiber pad with asphaltic coating on both sides
47	48	6-52	Burkart fiber pads, coated on bottom side
	427		Total

Notes: All pad sections have 2 each of cut line and anchor spikes. All sections, except Nos. 46 and 47, were installed with new AREA Plan 12 tie plates. Sections 46 and 47 have SH 14-in AREA Plan 6B tie plates. Plan 6B was withdrawn from the Manual in 1948.
Each test section has an oval tag on the north tie showing the section number, and every tenth tie from the north has a smaller tag showing the tie number.

Anchor Spikes Retightened

After completion of the detailed inspection in May 1954, a moderate amount of retightening of the special anchor spikes was performed. Each year, in addition to performing some spot maintenance in some sections, a few of the other sections are given their first out-of-face retightening, as needed. The work done in May 1954 has been summarized in Table 3. It will be of interest to read the footnotes of this table. In connection with some spot maintenance in section 11 with the Dowel studs, some of the studs were twisted off in trying to remove them for replacing the double-coil helical washers that were either missing or had broken into two single coils. These fastenings had a strong holding power in the oak ties and it was difficult to screw them out of the ties after tapping them down to break the bond in the wood. The Dowel studs have a neck on the shank between the threads for the nut on top and the threads for the part that is driven in the tie. The breaks all occurred in the neck portion. In several cases the nuts were frozen, and in the retightening the studs turned in the wood. To avoid more difficulty with the double-coil helical spring washers, all replacements will be made with the Thackeray type, which had had little breakage. Several of the single-coil washers were renewed in sections 10, 14 and 15 in the long 4½-deg curve. In section 10, the washers may have been damaged in driving the round head cut spikes, but in the case of the through bolts the load was wrenched on the washers. The service conditions and the shock loads on the through bolts should not be so severe as to break the thin low reaction spring washers. It will be noted in the footnotes of Table 3 that only a few screw spikes in sections 16 and 19 were found stripped in the wood. Although the traffic per annum has averaged over 20 million gross tons for the 7-year test, only a nominal amount of work has been required for the special anchor spikes. With good timber out-of-face and good maintenance of line and surface, it is logical that the special fastenings should require only nominal maintenance. However, more retightening will be required in the future.

Gage of Test Curves

Annual measurements of the track gage are made on the curves at 4 points in each panel of track (avoiding the joints in both rails), except that 6 points were used for the 5-deg 36-min curve where the gage holding capacity of compound 8 (now known as Tylife) and Rust Joint Iron is being investigated. A record of the gage of the two 4½-deg test curves is shown in Fig. 3. Good gage has been held by many of the special fastenings in the long 4½-deg curve for 7 years. In some of the cut spike sections, the track gage had more irregularity.

Since re-gaging section 21 with Fabco pads in the short 4½-deg test curve, September 1953, the gage had widened some, particularly in the north portion. In the fall of 1953 the curve was stringlined and placed in good surface, cross level and alinement. In addition, 2 cut anchor spikes were added to 4 cut line spikes in the outer rail of the south half of the section only. Prior to the inspection of May 1954, all of the AAR test track had been surfaced with a Matisa tamper and lined. With such an excellent maintenance program, it seems possible that the gage widening during the past year was influenced by the tie pads. This was evidently caused by a greater horizontal plate movement on the ties than that of the other test sections in the same curve.

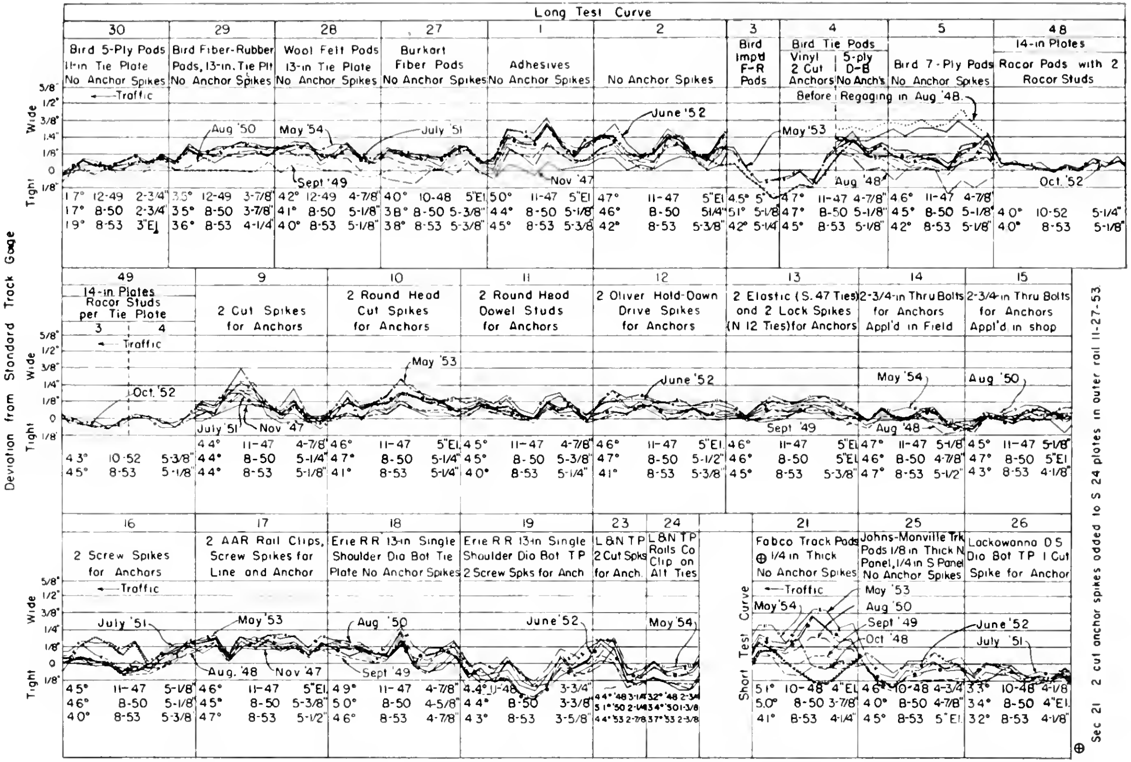
Fig. 4 gives a 4-year record of the track gage on the 5-deg curve at the East Bernstadt depot. Considering only the 4-year old sections (excluding sections 46 and 47), the track gage was held better in sections 42 and 43, having ⅛-in Dunne rubber pads and Racor studs, respectively. The total gage widening, including the effect of replacing the

(Text continued on page 844)

TABLE 3. HOLD-DOWN FASTENINGS TAPPED DOWN OR RETIGHTENED ON THE L&N RR NEAR LONDON, KENTUCKY - MAY 1954

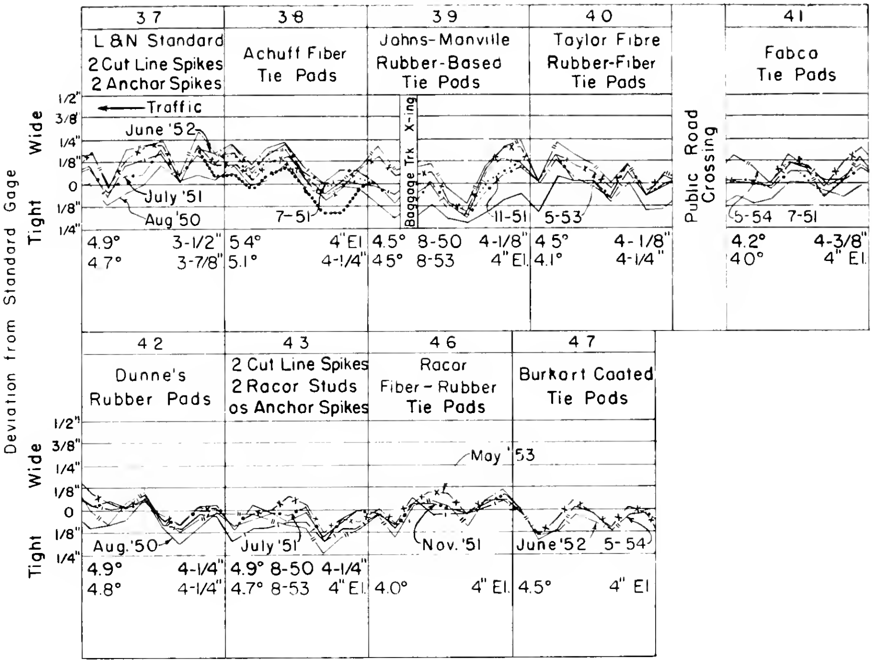
			Long 4° -30' Curve		Tangent Creo. Oak Ties		Tangent Creo. Pine Ties		Total for each Construction	
Sec. No.	Hold-Down Fastenings	Date Built	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
10	2-Round Head cut spikes with single-coil spring washers	8-47	(a) 48	21	0	0	0	0	48	8
11	2-Round Head Dowel studs with double coil hellcal spring washers	8-47	(b) 34	14	0	0	0	0	34	6
14	2-Thru bolts with single-coil spring washers (field)	8-47	(c) 188	100	0	0	0	0	188	51
15	2-Thru bolts with single-coil spring washers (shop)	8-47	(d) 192	100	0	0	0	0	192	52
16	2-Screw spikes with double coil washers	8-47	0	0	0	0	(e) 192	100	192	31
19	Erie diamond bottom tie plate, 2-screw spikes with double coil washers	8-47	(f) 236	100	-	-	-	-	236	100
31	G&H Controls No-Creep rail anchors, 2-Oliver Tie Plate Drive Spikes for anchors on alternate ties. (14-in tie plates)	8-49	-	-	(h) 96	100	-	-	96	100
	Totals		698	53	96	11	192	26	986	34

Notes. Col. (1). Number of anchor spikes retightened or tapped down. Col. (2). Percentage of anchor spikes retightened or tapped down. All tie plates have a flat bottom and a length of 13-in, except as indicated above. (a). Seven missing and 8 broken washers were replaced. (b). Three missing and 5 broken washers were replaced. Three dowel studs were sheared off in attempting to remove them to replace the washers. Three studs needing new washers were not removed to avoid breakage. Tapping down the studs in the hardwood ties facilitated removal, but some were twisted off. When retightening the studs without removal, the nuts were frozen and the studs turned in the wood. (c). Four missing and 20 broken washers were replaced. (d). Five broken washers were replaced. (e). Six broken washers were replaced and 2 screw spikes were found stripped in the wood. (f). One missing washer was replaced and three screw spikes were found stripped in the wood. (h). These drive spikes were applied, without washers, to the anchored ties only. All of this work was done manually and required 20 man-hours.



Note: All test sections have 13 in Plan 5B (Modified) tie plates with flat rail seat except those shown otherwise and as follows Sec 17, Penn R R 14-3/4 in tie plate sheared to a 13 in length; Sections 23 and 24, 14 in AREA tie plate, Sec 26, 13 in Lackawana double shoulder diamond bottom tie plate, Sections 27, 28 and 29, S H Plan 5B with rolled crown and also in Sec 30, except cut to 11 in length. All sections without anchor spikes have four line spikes and sections with anchor spikes have two line spikes. Sec 26 has 2 cut line spikes and 1 anchor spike.
—— After replacing pads in 1952 ++++++ After replacing outer rail 9-23-53 -·-·-· After regaging 9-23-53.

Fig 3 - Gage, Curvature and Elevation of Each Section of Test Track on the 4°-30' Curves, Mile L-154, L&N R R, near London, Ky



Sections 37 thru 43 have AREA 14-in Plan 12 flat bottom tie plates.
Sections 46 and 47 have second hand AREA Plan 6B flat bottom tie plates.
All sections have two each of cut spikes for line and anchor except as noted. ····After replacing pads in 1951 ---- After replacing pads in 1952

Fig. 4 Gage, Curvature and Elevation of Each Section of Test Track on the 5-deg Curve, Mile L-153, L.& N.R.R., at East Bernstadt, Ky.

tie pads, was largest in section 38, with Achuff pads, followed by section 39, with J–M pads.

Fig. 5 covers the track gage measurements of the tests involving the use of Compound 8 and Rust Joint Iron in spike holes of the ties to compare their gage-holding capacity with the L&N standard construction in the 5-deg 36-min curve. This curve is the second one north of the East Bernstadt depot in the northward main, and is near the summit of a long descending grade. In the figure, the change in gage between the curves for June and August 1952 was brought about by removing the gage rods from the nine panels of track. Since completion of the test installation, August 1952, there have been no significant differences in the average gage widening of the three sections. Because of the good tie condition in the test curve, it may not be possible to develop the merits of the two compounds. Laboratory tests have shown that both of the compounds were effective in restoring the withdrawal power of cut spikes in simulated spike killed hardwood ties.

General Inspection

This inspection was made by members of the AAR research staff in May 1954, except that the examination of tie pads by removal was conducted on July 21, when

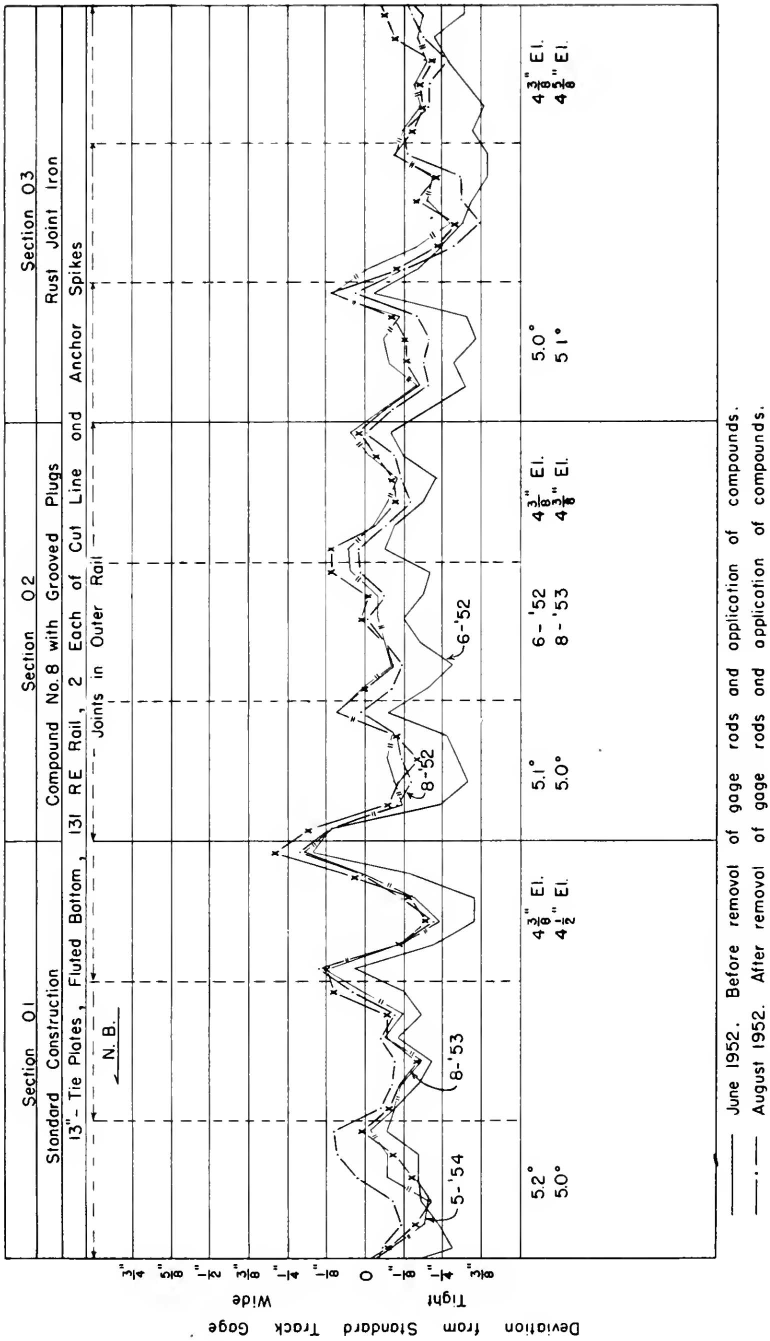


Fig. 5 Gage, Curvature and Elevation of Sections 01, 02, and 03 in 5°-36' Curve, Mile L-152, L. & N. R.R.

members of the Track committee and guests were present. The inspection party of 13 persons, in addition to 2 AAR research staff members, included 3 subcommittee members or their representatives, 3 AREA associate members and 7 guests representing 5 manufacturers.

Tie Pads

Twenty tie pads were removed for inspection, and Figs. 6 to 25, incl., are included to show the condition of the pads and adzed surfaces. Brief comments on the conditions observed have been noted below the title for each figure.

A slight compression of the springwood was observed under the field end of the tie plates in the inner rail of the 5-deg test curve. Service conditions on this curve are more severe than on the two 4½-deg curves because of more traffic operating below the balanced speed of the curve.

In last year's report the general condition of most of the tie pads was described in detail. The condition of the pads during the past year has not changed significantly. The various kinds of pad damage, characteristic of each type, has progressed moderately. There has been no sudden failure or accelerated deterioration of the tie pads. It is reasonable to assume, for the conditions of the L&N test, that some of the tie pads showing the better performance should have a service life of at least 10 years, in which the gross tons of traffic will amount to over 200 million. All of the tie pad tests have been conducted with new pre-adzed ties and flat-bottom tie plates.

Based on the service tests of tie pads since 1947 for different service periods (as shown in years in the parentheses following each pad designation), the following tie pads have shown the better performance: Bird original fiber-rubber (5); Bird improved fiber-rubber (2); Fabco (7, 6, 4 and 3); Bird 5 and 7-ply duck-burlap (6 and 5); Burkart fiber (6 and 2); Dunne's molded rubber (4); Racor fiber-rubber (2.7 and 2); and Bird vinyl pads (2).

Hold-Down Fastenings

In last year's report, the results of a triennial measurement of the tie abrasion were published and the special fastenings were rated as to their effectiveness. In addition, the deficiencies of some of the test fastenings were discussed.

So far, the total maintenance work performed on the special fastenings, as judged from the percentage of fastenings retightened, is as follows: sections 17, 19 and 31—100 percent or over; sections 10, 14, 15 and 22—69 to 77 percent; section 16—37 percent; section 12—29 percent; section 11—14 percent; and the Elastic spikes in section 13—9 percent. No work has been done on the Tie Plate Lock spikes in sections 13 and 34. All of the Racor studs were tapped down once with a pneumatic hammer after installation because the fastenings were not driven home manually.

This year difficulty was encountered in performing work on the Dowel studs in section 11. Although the Dowel studs have been very effective in reducing plate cutting and in holding gage on the curve, the extra expense in unfreezing the nuts and replacing the broken washers will detract from the economy of this type of fastening. Although the work involved in replacing broken spring washers on the special fastenings was not a reflection on the fastening, it will be difficult to disassociate the extra expense from that of maintaining the fastening.

Less than 2 percent of the 380 through bolts in the long 4½-deg test curve had frozen nuts. These were unfrozen by nicking them with a track chisel.

(Text continued on page 857)

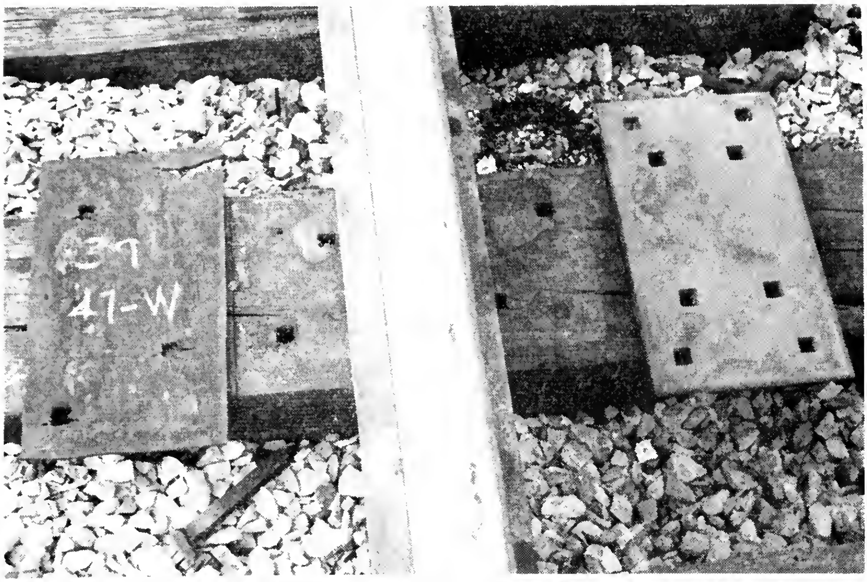


Fig. 6. South Portion S[illegible] 14-[illegible] Mansville Rubber Composition [illegible] Pad [illegible] Coated. After [illegible] Months' Service in the Inner Rail [illegible] 5° Curve

Poor seal, some sand at gage end [illegible] coating left on tie, none on pad, and [illegible] compression of wood at field end.

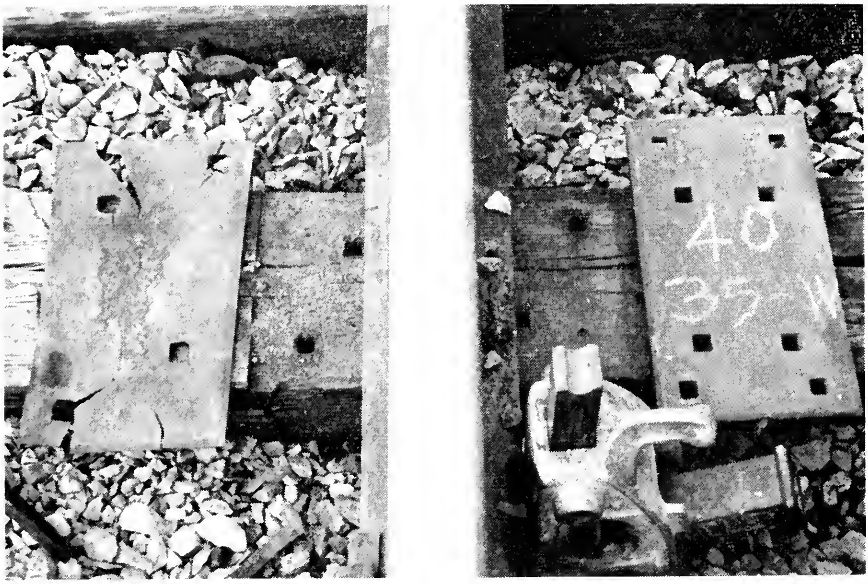


Fig. 7. Section 40, 14-in Taylor Fibre Co. Laminated Rubber - Vulcanized Fiber Tie Pad, Uncoated, After 4-years' Service in the Inner Rail of the 5° Curve

Picture shows condition of fiber layer. Rubber layer was in reasonably good condition. No seal, some sand and slight compression of wood at field end. Plies are separated.

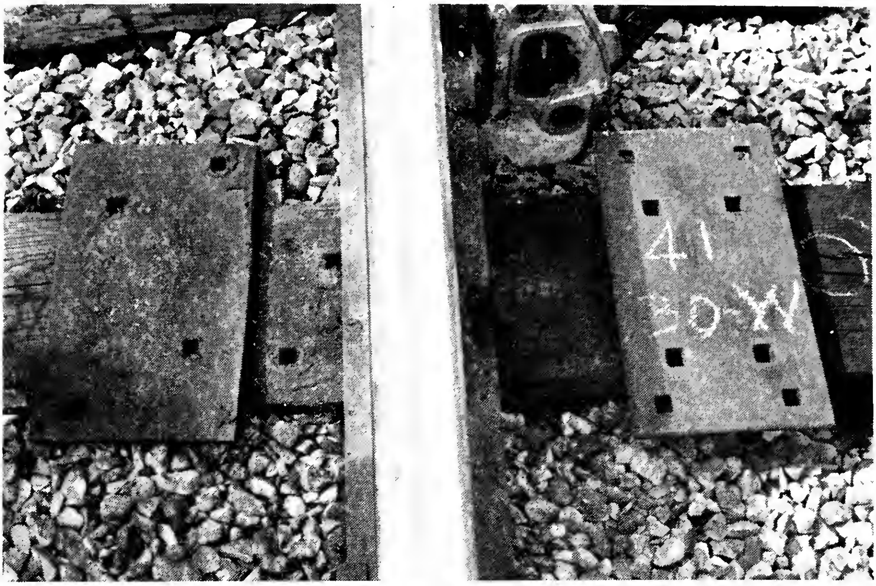


Fig. 8. Middle Portion Section 41, 14-in (1951) Fabco Tie Pad, Bottom Coated, After 3-years' Service in the Inner Rail of the 5° Curve

Little seal, 2/3 coating left on tie, some sand, no abrasion or springwood compression, pad condition good.

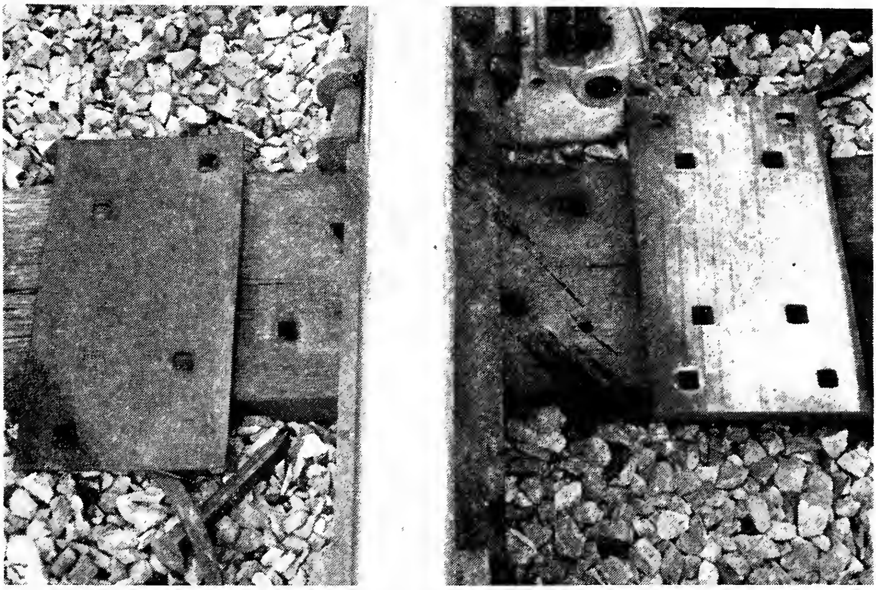


Fig. 9. Section 42, Dunne Rubber Co. 14-in Molded Rubber Tie Pad, 1/8-in Thick, Uncoated, After 4-years' Service in the Inner Rail of the 5° Curve

Some sand, slight abrasion and compression of springwood caused by the ridges on the pad, pad in good condition except for a little compression at the field end. Note that the sand imbedded in the ridges of the pad and abraded their pattern into the tie plate.

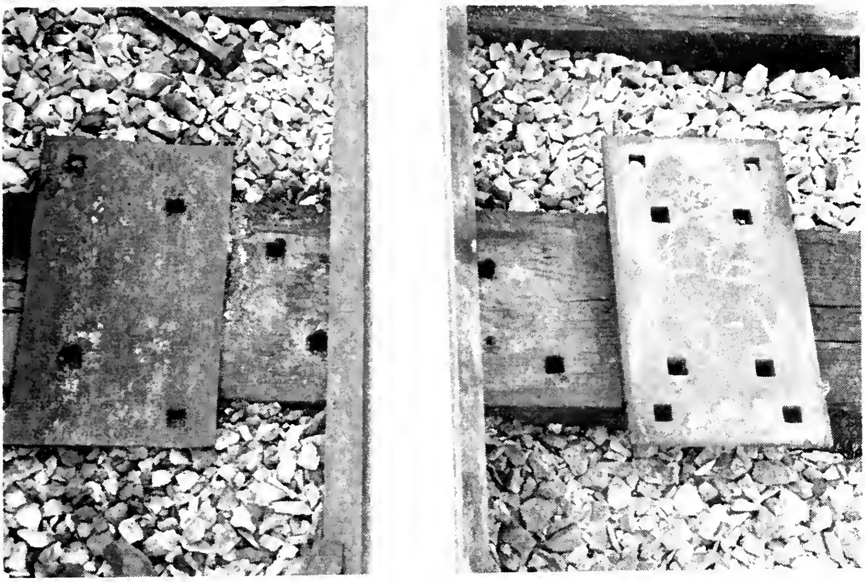


Fig. 10. North Portion Section 46, 14-in Racor Tie Pad, Uncoated, After 32-months' Service in the Inner Rail of the 5° Curve
Little sand, pad in good condition.

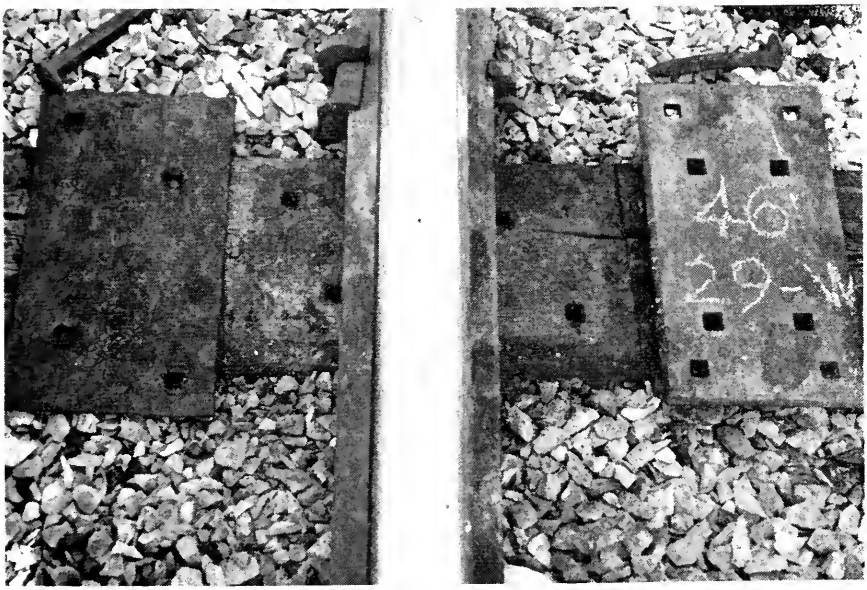


Fig. 11. South Portion Section 46, 14-in Racor Tie Pad, Coated, After 32-months' Service in the Inner Rail of the 5° Curve
Little sand, fair seal, 80 percent coating left on tie, pad in good condition.

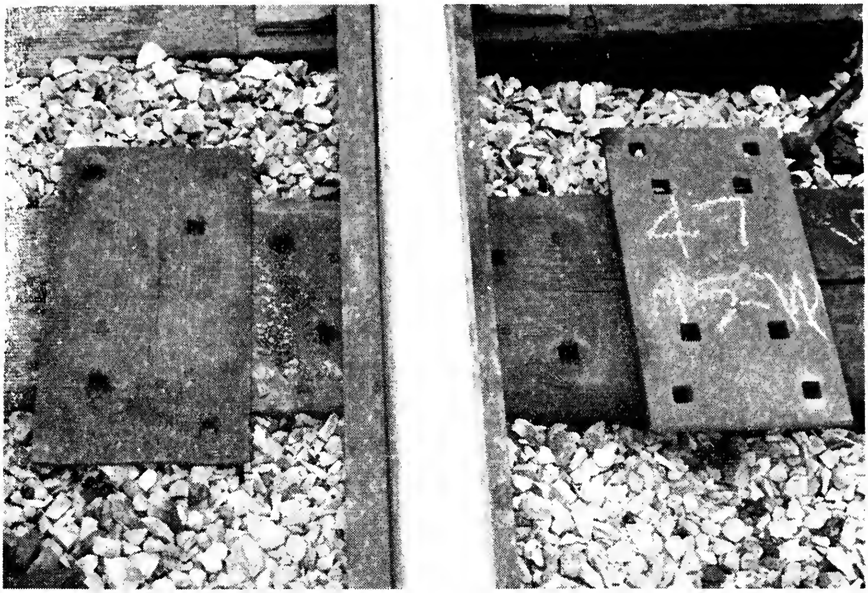


Fig. 12. Section 47, 14-in Burkart Tie Pad, Bottom Coated, After 25 months' Service in the Inner Rail of the 5° Curve

The gage end of tie plate was bent upward and some sand and pebbles were found there. Balance of under-pad area was clean. Most of the coating had disappeared from the pad and tie. Fair seal, no abrasion or compression of wood, pad condition good.

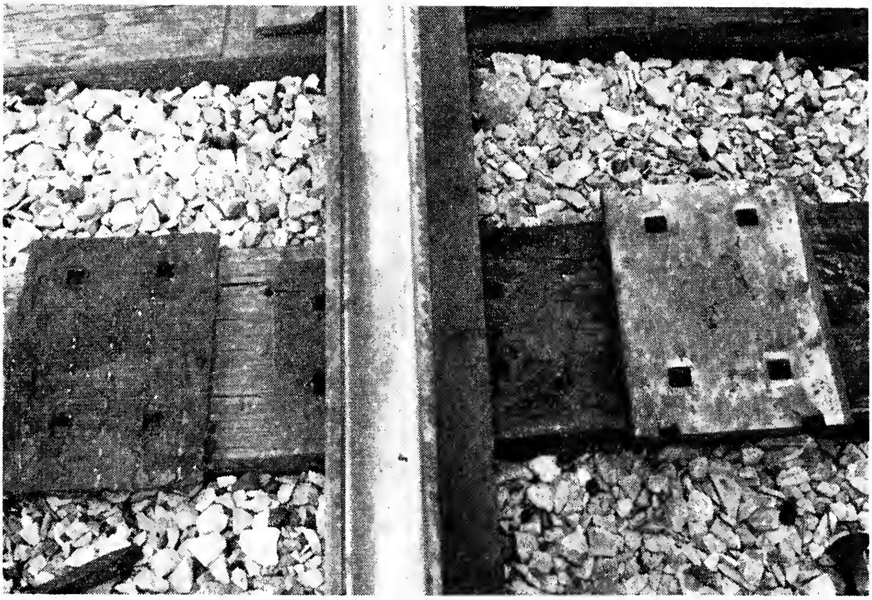


Fig. 13. Section 39, 11-in Bird 5-ply Duck-Burlap Tie Pad, Coated, After 58-months' Service in the Outer Rail of the North Spiral of the Long 4-1/2° Curve

Pad sealed, except at field end, pad condition good.

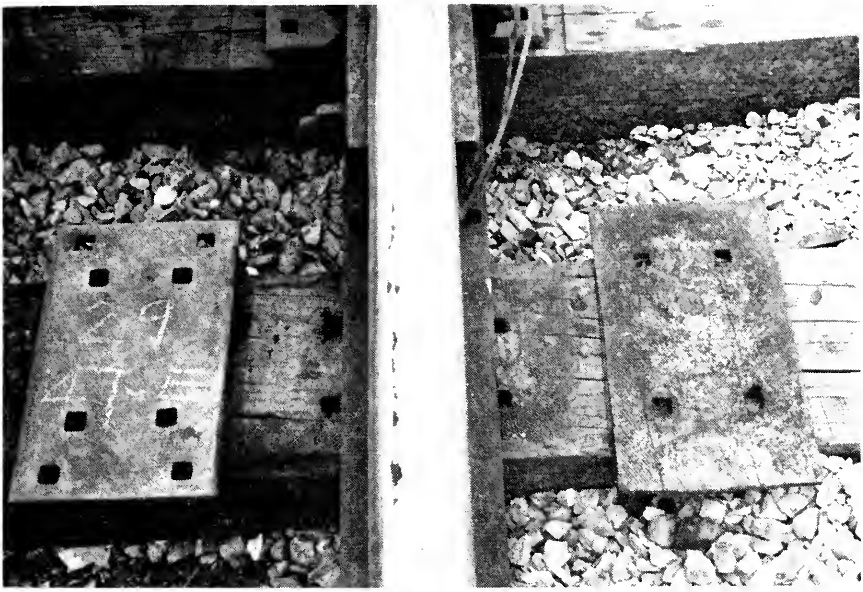


Fig. 14. Section 29, 13-in Bird Original Fiber-Rubber Pad, Serrated Surfaces, Coated, After [illegible] months' Service in the Inner Rail of the Long 4-1/2° Curve

Little sand and compression of springwood, most of coating abraded from pad, [illegible] of wood, pad not sealed, but was in good condition.

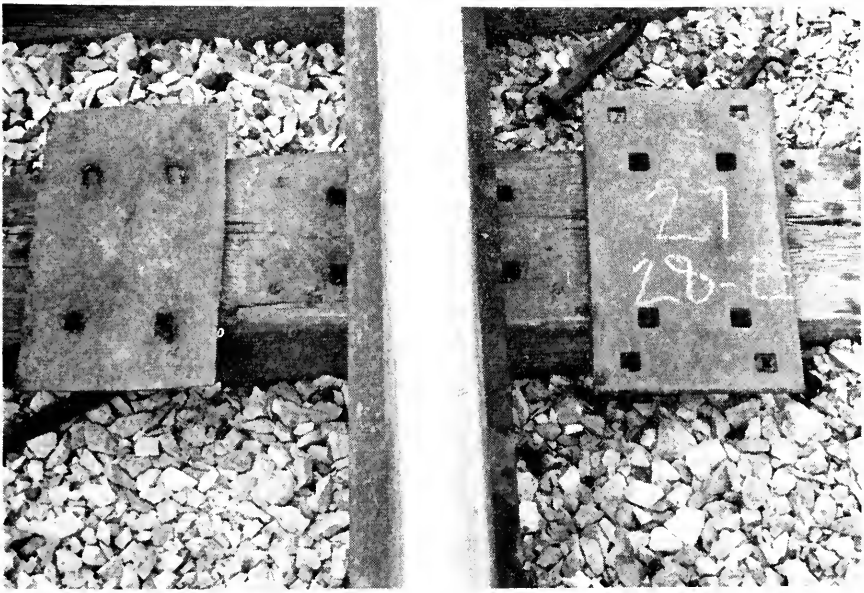


Fig. 15. Section 27, 13-in Burkart Fiber-Pad, Uncoated, After 68-months' Service in the Inner Rail of the Long 4-1/2° Curve

Little sand, slight spring wood compression at field end, pad condition good.

Fig. 16. Section 3, 13-in Bird Improved Fiber-Rubber Tie Pad, Abraded Surfaces, Coated, After 25-months' Service in the Inner Rail of the Long 4-1/2° Curve

Good seal 1/2 pad area, little sand, pad in good condition.

Fig. 17. North Portion Section 4, 13-in Bird Vinyl Tie Pad, Coated, After 25-months' Service in the Inner Rail of the Long 4-1/2° Curve

Pad sealed hard and lifted with a foot adze. Pad and wood under it were in good condition.

Fig. 18. South Portion Section 1, 1[illegible]-in [illegible]-ply Duck-Burlap Tie Pad, Coated, A[illegible] 7[illegible] [illegible] Rail of the Long 4-1/2° Curve

Hard and tight seal, pad lifted with foot [illegible], no abrasion or compression [illegible] the wood, [illegible]

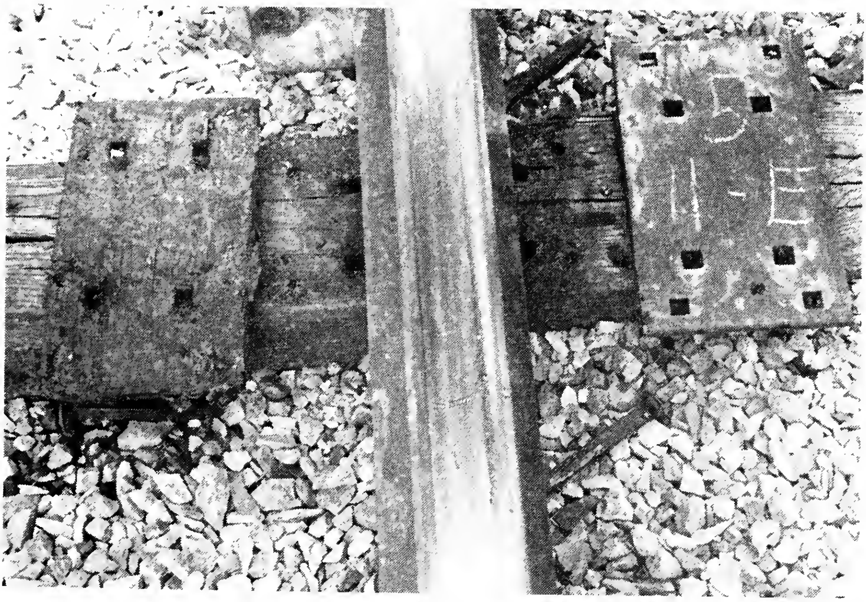


Fig. 19. North Portion Section 5, 13-in Bird 7-ply Duck-Burlap Tie Pad, Coated, After 71 months' Service on the Inner Rail of the Long 4-1/2° Curve

Hard and tight seal, pad and wood in good condition.

Fig. 20. South Portion Section 5, 13-in Bird 7-ply Duck-Felt Tie Pad, Coated, After 83-months' Service in the Inner Rail of the Long 4-1/2° Curve

Good seal, clean surface, wood in good condition. The top ply of this pad was damaged and dislocated.

Fig. 21. Section 48, 14-in Racor Tie Pad, Coated, and Racor Studs, After 23-months' Service in the Inner Rail of the Long 4-1/2° Curve

Pad was bonded well to tie plate and tie. Pad and wood in good condition.

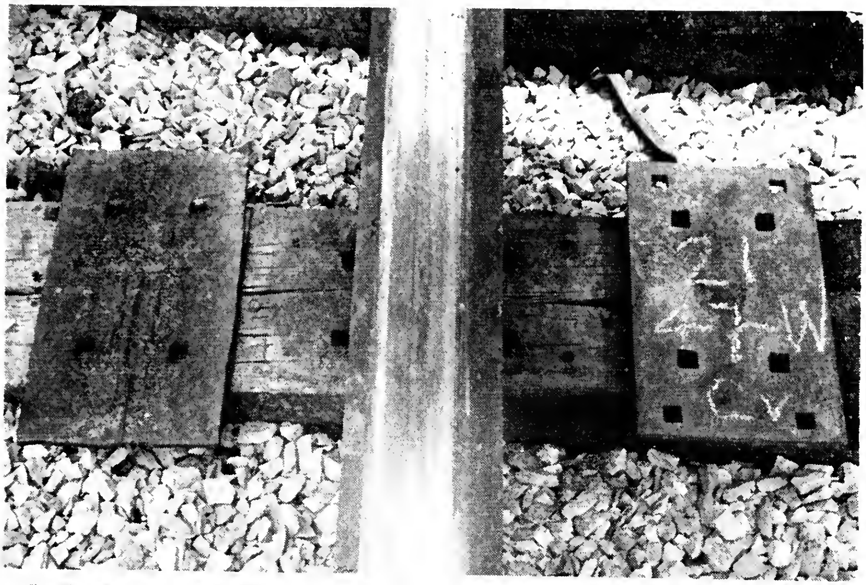


Fig. 22. Section 21. [illegible] Tie Pad, [illegible] After [illegible] Service in the Inner Rail of the Short 4-1/2° Curve

[illegible]

Fig. 23. North Portion Section 25, 13-in J-M Laminated Asbestos Rubber Tie Pad, [illegible] in thick, Uncoated. After 71-months' Service in the Inner Rail of the Short 11-1/2° Curve

Little sand and some tie abrasion. Maximum depth [illegible] 0.025 in. [illegible] pad was in excellent physical condition, except for some [illegible] at the [illegible]

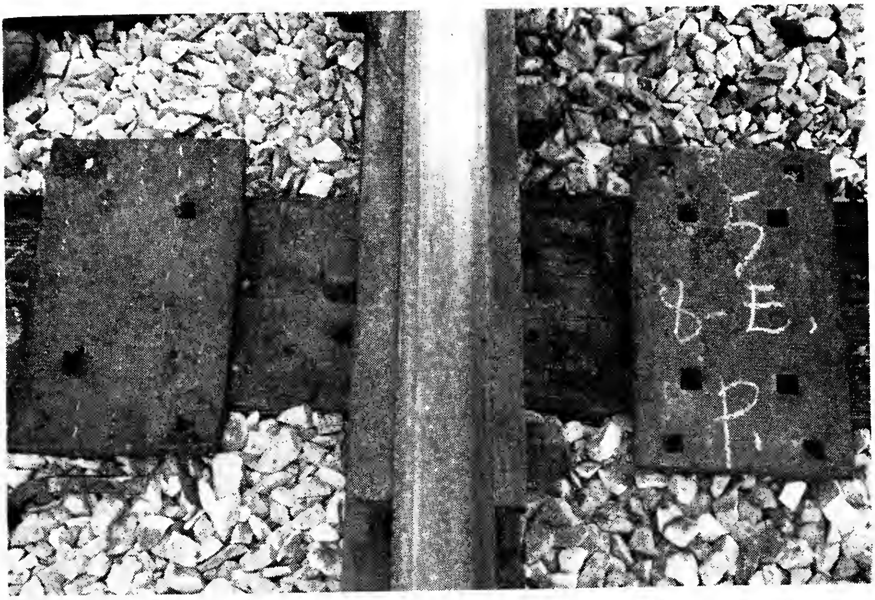


Fig. 24. Section 5, 13-in Bird 7-ply Duck-Felt Tie Pad, Coated, After 83-months' Service on a Creosoted Pine Joint Tie in Tangent Track

Fair seal, clean tie surface, some wood compression, pad condition good. Most of the coating had been abraded away.

Fig. 25. Section 21, 13-in Fabco Tie Pad, Uncoated, After 83-months' Service on a Creosoted Pine Joint Tie in Tangent Track

Some wood compression and pitting by the sand and pebbles under the pad. Pad condition moderately good.

Tie Coating

In July 1950 two test sections were installed in tangent track by applying Koppers No. 16 sealing compound to the tops and ends of the ties to determine its capacity for retarding the splitting and weathering of new and existing creosoted hardwood ties. Section 35, consisting of 120 new ties, had the odd numbered ties coated on top; the others were left uncoated for controls. In addition to coatings the adzed surfaces of all of the new ties, the compound was also brushed on the ends of the coated ties in the south half of the section. Section 36, consisting of 118 existing creosoted hardwood ties, had all ties coated on top and also the ends of the south 58 ties. The tops of all coated ties were sprinkled with ¼-in washed gravel to serve as a protective covering. W. J. Finnorn, Timber Engineering Company, with the assistance of a member of the AAR research staff, made the fourth annual inspection in July 1954.

The efficiency of the coating for keeping the splits and checks covered was determined from the number of exposed splits ⅛ in wide or greater on the top end faces of the ties. The efficiency factor for the new ties in section 35 was obtained from the following formula:

$$\text{Efficiency, percent} = 100 - \left(\frac{\text{Number of checks in coated ties}}{\text{Number of checks in uncoated ties}}\right) \times 100$$

Because all of the ties were coated in section 36, the original number of checks in the ties before being coated was used as the base for the efficiency factors.

Values of the coverage efficiency of the coating during the 4-year test are as follows:

Category	*Section 35—New Ties Percent*				*Section 36—Existing Ties Percent*			
	1951	*1952*	*1953*	*1954*	*1951*	*1952*	*1953*	*1954*
All coated ties	75	74	76	52	82	82	70	48
Ties coated on top only	70	63	73	48	64	75	61	36
Ties coated on top and ends	79	85	80	55	97	89	79	60

This year, for the first time, there was a marked drop in the efficiency factors for all categories listed above. For the ties coated on top only, which represents the normal use of sealing compounds, the efficiency factor dropped from 73 to 48 percent and from 61 to 36 percent for the new and existing ties, respectively. Since last year's report the test sections were surfaced out-of-face with a Matisa tamper. The coating has weathered off of some areas and worn thin in others by the elements, and by plowing ballast out of the track. The coating did not appear to have chipped or flaked off. More of the coating had disappeared from the existing ties than from the new ties. Photographic views of the two test sections are shown in Figs. 26 and 27.

Readings were taken on the top surface moisture content of the ties with a Delhorst moisture detector, the electrodes being driven to a depth of ⅜ in.

Averages of these readings in percent for the 4-year period are summarized in the table below:

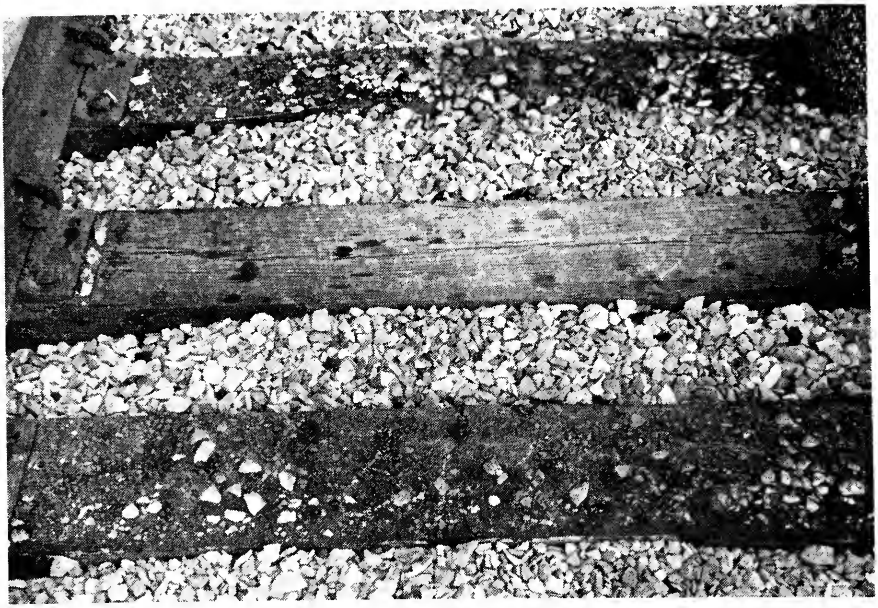


Fig. 26. Section 35, Koppers' No. 16 Sealing Compound on Alternate New Creosoted Oak Ties in Tangent Track After 4-years' Service

The coating was originally sprinkled with a protective covering of 1/4-in washed gravel.

Fig. 27. Section 36, Koppers' No. 16 Sealing Compound on Existing Creosoted Hardwood Ties in Tangent Track After 4-years' Service

The coating had weathered away on a few areas. The coating was originally sprinkled with a protective coverin of 1/4-in washed gravel.

Date	*Section 35—New Ties*			*Section 36—Existing Ties*		
	Coated	*Uncoated*	*Difference*	*Coated*	*Uncoated*	*Difference*
July 1951	16.5	10.2	6.3	----------	----------	----------
June 1952	20.6	10.9	9.7	29.8	12.3	17.5
July 1953	18.5	11.8	6.7	24.7	11.5	13.2
July 1954	11.9	9.3	2.6	12.2	8.8	3.4

Prior to the last set of readings, the weather had been dry and hot for a month. The summer of 1953 was also hotter than normal. This year the average moisture content of the top surface of both new and existing coated ties reached an all-time low value. The excess moisture content of the coated ties over that of the uncoated ties also dropped sharply. The coating had been much less effective during the last year in retaining a higher moisture content in the top ⅜ in of the ties.

After four years of service, the coating has become less effective in keeping the splits covered and the moisture in the tops of the ties. It is probable that the effective life of the coating will not exceed 5 or 6 years.

Conclusions

Because the Koppers No. 16 sealing compound used as a coating on the ties to retard splitting and weathering of the creosoted hardwood ties had a sharp drop in effectiveness after a service period of 4 years, it is probable that its service life will not exceed 5 or 6 years. The coated tie pads have provided better protection of the under-plate area of the tie than the uncoated pads. The service tests have been of too short duration to determine the economy of the tie pads and hold-down fastenings. However, the tie pads that have given the better service performance for periods of 2 to 7 years have been listed herein. A precise appraisal of the special hold-down fastenings cannot be made for the present. However, in last year's report the fastenings were rated as to efficiency in reducing plate cutting, and this report gives a summary of the maintenance required.

Acknowledgement

The Association is indebted to the L&N for its fine cooperation and assistance in the conduct of the service tests and extends its appreciation to the cooperating manufacturers and their representatives.

Report on Assignment 7

Effect of Lubrication in Preventing Frozen Rail Joints and Retarding Corrosion of Rail and Fastenings

R. G. Garland (chairman, subcommittee), L. L. Adams, Blair Blowers, R. J. Bruce, W. E. Cornell, E. D. Cowlin, H. W. Cox, Jr., K. E. Dunn, W. E. Griffiths, J. W. Hopkins, H. B. Orr, J. M. Rankin, M. K. Ruppert, G. R. Sproles, R. E. Tew, J. B. Wilson.

TESTS ON THE ILLINOIS CENTRAL

This is a report of progress of the four-year old rail joint lubrication service tests on the Illinois Central Railroad, and is offered as information.

Introduction

The original test of 10 sections was installed in the northward main of the IC in June 1950, when the track was relaid with 132 RE rail and 6-hole headfree joint bars. Two stretches of track were involved: one south of Chebanse, Ill., the other south of Ashkum, Ill. All of the track in and near the test sections is tangent with light grades, and carries fast traffic. From 10 to 20 percent of the traffic is reversed movements. All of the passenger traffic is hauled by diesel power and most of the freight tonnage is hauled by heavy steam locomotives of the 4–8–2 type. During the fourth service period of 11⅓ months, ended July 23, 1954, the test track carried 27 million gross tons of traffic. Since the initial test measurements were taken in August 1950, the total gross tonnage has amounted to 126.9 million.

After two years of service, two of the sections having a brush coat of Dixon's 1924 Quick Drying Lubricant and Farbertite had failed because of forming a hard coating which was susceptible to flaking off with the mill scale or from vibration of the rail. In last year's report (Vol. 55, 1954, page 749), the changes made in these sections were described. The joints in the west and east rails of section 3 were first sprayed in July 1953 with Texaco No. 941 rail joint lubricant and Leadolene Barcote No. 600, respectively. A reapplication of the two lubricants was made in August 1954. The joints in section 10 were sprayed first with Texaco TA–2420 and a year later with Texaco RCX–236. The former compound was made by adding a wetting agent to Texaco No. 55. TA–2420 was further improved by using less asphalt and more lubricating oil to form the RCX–236 preservative. RCX–236 is said to have better flowing and penetrating properties and slower oxidation and hardening of the coating than TA–2420. Fig. 1* is included to show the location and description of the test sections as revised.

Discussion of Test Data

Rail Joint Gap

Measurements of the rail gap width were repeated for the last winter and summer, and have been summarized by the bar diagrams shown in Figs. 2 and 3. During the last service period, the winter rail gap measurements showed no increase in the percentage of the joints in the two lower increments of rail gap width. The last two sets of summer measurements indicated that there had been no decrease in the percentage of joints in the two lower increments. It follows that there has been no increase in the tendency for the joints to become frozen. From Fig. 2 it will be observed that no section had a superior uniformity of rail gap width for the last winter. From the diagrams in Fig. 3

* All figures referred to in this report are represented at the end of the report.

for last summer, the uniformity of the rail gap was best in section 10 and in the east rail of section 3. This is of little significance for section 10, as the measurements included only 20 joints in the west rail, compared with about 68 for the other sections. Sections 6 and 1 had the lowest percentage of joints in the first increment. No test measurements were taken in the east rail of section 3 until after the joint bars were sprayed with Barcote No. 600, July 1953. This section also had good uniformity of rail gap width for the summer of last year. Because the average summer rail gap in sections 10 and 3 (east rail) was much smaller than in all other sections, it is possible that the rail was laid tighter. From the test data available, it cannot be determined if Barcote No. 600 was a factor in creating a better rail gap uniformity.

A comparison of the rail gap uniformity can be made for Texaco No. 941 and TA–2420 because of their being in the west rail where all measurements have previously been taken. There was no significant improvement of the rail gap uniformity of these two sections between the winters before and after the first spray application. The difference between the two last summer measurements indicated a slight improvement of the rail gap uniformity in section 10 with Texaco TA–2420 and a moderate improvement in section 3–W with Texaco No. 941.

Rail gap uniformity for the two seasons of measurements has not been influenced appreciably by the type of lubricant used during this test, or the 6-year test on the Chicago, Burlington & Quincy Railroad.

Joint Bar Pull-In

The joint bar pull-in, or total joint wear, measurements are presented graphically in Fig. 4. The average pull-in for the 4-year period ranged from 0.057 in to 0.072 in. The average for all test sections was 0.066 in, or about 0.016 in per annum. This latter figure compares well with the average pull-in of 0.015 in found in several bolt tension tests. There were no important differences in the pull-in of the sections having a brush coat of a preservative on the rail only or on the rail and joint bars. The average pull-in in the sections without lubrication was comparable to some of the sections with preservatives. So far, there was no indication that respraying the joints has reduced the joint wear.

Maintenance-of-Way Report

During the fourth service period the IC reported one loose and two broken bolts. The loose bolt and one broken bolt were reported for section 1, and the other broken bolt for section 8. Both of the bolts failed because the heads broke off. In 4.58 miles of test track during the 4-year service period, only 3 bolts were found broken and one loose. No joints have pulled in two. For the purpose of this report, a loose bolt is one that has no tension. Each autumn the bolts are retightened with power track wrenches.

Inspection of End Plugs

Each summer all of the Texaco Plastic H end plugs are inspected. The No–Ox–Id end plugs in section 4 slumped to about one-half of their height during the first summer. There is a total of 1740 plastic H end plugs—980 square end plugs in sections 7 and 8 and 760 beveled end plugs in sections 2, 5 and 9. Twenty, or 2.0 percent, of the square end plugs had worked out. Forty, or 5.3 percent, of the beveled plugs were out of place.

Inspection of Dismantled Joints

This year the annual inspection was made by the subcommittee on August 4, 1954, and the three sections first sprayed last year were resprayed the following day. This was the second successive year of good attendance at the inspection. In addition to the photographer of the Burlington Road, supervisor of track of the IC, and the AAR research engineer of track, there were 17 persons in the inspection party, including 8 representatives of 6 railroads and 9 representatives of 5 manufacturers. In the group there were 4 subcommittee members, 4 other AREA members, and 1 associate member. Fifteen joints were inspected by removing the bars. Photographs are presented for 13 joints in Figs. 5 to 17, incl. The last 3 figures show the condition of the joints first sprayed last year. Each of the foregoing photographs is a composite view showing the bottom as well as the top fishings of the bars. The Association is indebted to the Burlington for the splendid service rendered by its photographer.

During the night before the inspection, a moderate rain fell. Consequently, the presence of free water in the joints precluded detection of condensation in a joint that could be attributed to the lack of ventilation or drainage in plugged or packed joints. Although the original installation of the several compounds was made 15 to 20 min after the rails were end hardened, the heat left in the joints caused the greases to melt off the middle third of the joints and may have damaged the grease cakes in the same area.

In Fig. 5, the RMC plastic joint packing had dried and hardened some. This formula of grease cake apparently had less cohesion than the original one used in the Burlington test, because of separation of the packing. Corrosion was observed on the upper rail web and fillet, the latter being more severe. This material provided good protection for the bolts. As a matter of interest, Fig. 21 is included to show the condition of the original formula packing on the Burlington, also after 4 years of service. The old formula packing exuded more oil than the new ones and retained its shape better. The grease cakes are deficient at the top fishings but provide reasonably good protection for the lower half of the rail and bars. In the Burlington test, the rail was not end hardened.

Figs. 6 and 7 show two joints protected with a brush coat of Conoco Anti-Rust Compound, and in addition, one of the joints had end plugs. The joint with the end plugs was in better condition in that (1) much less corrosion was observed in the upper rail fillets, and (2) was cleaner. Free water can be observed in both figures.

Views of two joints in section 4, Figs. 8 and 9, show the difference between the two methods of applying a brush coat of No-Ox-Id "A" Special. In Fig. 8, the joint bars had more coverage by the preservative and less corrosion than in Fig. 9, which had a brush coat applied to the rail only. The rail web in Fig. 8 had a little better coverage by the preservative than in Fig. 9. The No-Ox-Id end plugs melted down during the first summer.

Figs. 10 and 11 cover the joints in sections 5 and 6 without lubrication. There was some oil present on the rail and bottom of the joint bars that was applied in spraying the new rail in 1951. Neither joint had hard rust slabs in the lower rail fillets. The condition of the joints as to corrosion and debris was about equal. In Fig. 10, one plug had part of the heel missing and the other had a good bond.

Fig. 12 and 13 give a comparison of packing joints solid with Texaco No. 905 grease and Petrolatum (dark), respectively. The joint in section 7 with Texaco 905 grease had exuded some grease at the bolts. The rail web and upper and lower fillets were well preserved. Some leakage of the grease had occurred at the rail gap. There was no corrosion in the upper rail fillets.

Although about 85 percent of the Petrolatum (dark) had flowed out of the joint in Fig. 13, it was well preserved by a thin coat of preservative, which may disappear in another year or two. There was very little corrosion on the bars or rail. The Petrolatum has a low melting point and flows out during hot weather.

Both of the packed joints have been preserved better than in the other sections. The bolts wer well lubricated. The top fishings of the joint with Texaco 905 had some lubrication, but they were rather dry in the joint with Petrolatum (dark).

The joint having a brush coat of Petrolatum (dark) and Plastic H receiving end plugs (Fig. 14) showed evidence of excessive heat. The fishings were dry except for small areas on the bottom of the bars. In comparing Fig. 14 with Fig. 7, the latter joint with Conoco Anti-Rust Compound and both ends plugged, was much better preserved than the joint in Fig. 14 with receiving end plugs only. In order to show comparative conditions in this test and the Burlington test, Fig. 22 is included. Both joints had a brush coat of Petrolatum (dark). On the Burlington, the rail was not end hardened and there was not heat to cause the grease to be melted. Because of cool weather the Petrolatum (dark) was heated for applying the brush coat to the rail only. It was also necessary to heat the Petrolatum on the IC, but the weather was warmer. The Burlington joint, Fig. 22, after four years, was much better preserved.

Figs. 15, 16 and 17 show the condition of the joints sprayed, respectively, with Texaco No. 941, Barcote No. 600, and Texaco TA–2420. Little of the spray coat was left on the fishings. The rail web with a coating of Barcote 600 appeared to be protected best, and the condition of the TA–2420 the worst. The latter joint had some lubrication on the bottom of the bars for a length of 6 in at the receiving end. Because only one joint for each spray coat was inspected, it was not possible to determine precisely the relative performance of the three preservatives.

Respraying Operation

The three sections that were first sprayed in 1953 were resprayed on the day followign the last inspection, using the same lubricants in section 3 and substituting Texaco RCX–236 (previously described) for TA–2420. The work was performed by using the same equipment as described in the last report. However, a change in nozzles was made by using the design developed by the Atchison, Topeka & Santa Fe Railway. These had a much larger orifice than those used on the top of the bars last year, and could be moved past the bolts, behind the bars. The nozzle used behind the bars had the spray in a vertical plane, was tilted upward and pushed to the second bolt from the end of the joints. As the nozzle was withdrawn from each end of the bars, the valve was opened. The other nozzle was moved along the top of the bars for coating the top fishings.

A photograph of a typical joint in each of the three test sections is shown in Figs. 18, 19 and 20. The fishings were well covered, but the coverage on the web of the rail was incomplete. From the few joints inspected it was observed that Texaco 941 was the most rapid for penetration and flowing qualities. It was thinner than the other two spraying compounds. The RCX–236 appeared to have better flowing properties than the TA–2420 used last year.

The day was cloudy and cool, with a temperature of 78 deg F at mid-morning. Because of the large nozzle, the spray pressure was held as low as possible for proper atomization, or from 50 to 75 psi. Because of the limited heat output of the machine, the maximum temperatures of the three materials was only 88 deg for Texaco 941, 80 deg for Barcote 600, and 84 deg for RCX–236. The latter compound was too cool for obtaining the proper atomization. The materials in pounds per joint used this year compared with last year follow: Texaco 941, 2.0 vs 1.6; Barcote 600, 1.3 vs 1.4, and 1.2 of RCX–236 vs 1.4 of TA–2420. The larger nozzle was suitable for handling the heavier materials, but was too large for the Texaco No. 941, which is thinner when heated. An appreciable amount of Texaco No. 941 ran out of the joints and was wasted.

From inspections next year it will be decided when the joints will be sprayed the third time. It is proposed to use another type of nozzle that will give good coverage inside of the joints and require less lubricant or preservative.

General Remarks

The joint packed with Texaco 905 grease and Plastic H end plugs had been protected from corrosion the best. The joint packed with Petrolatum (dark) ranked next. However, because most of the latter material had melted and leaked out of the joint, the future performance of the material may be limited. The joints in section 8 with a brush coat of Petrolatum (dark) and receiving end plugs had the poorest protection.

After four years, the superior coverage of a preservative brushed on the bars and rail, compared with brushing the rail only, was not as prominent as in previous years.

The joints packed with Texaco No. 905 were the only one in which the lubrication on the top fishings was maintained to an important extent.

The sections sprayed last year had very little lubrication left on the fishings. The first spray application in two of the sections effected a slight to moderate improvement in the summer rail gap uniformity. Conclusions as to wear of the sprayed joints will require a longer service period.

The performance of the sections protected with a brush coat of Petrolatum or Petrolatum-based products was handicapped by the heat left in the joint from the end hardening operation.

The new formula RMC plastic joint packing had exuded less oil than the old formula grease cakes.

Judging from the condition of the brush coat of Petrolatum (dark) in section 9, the receiving end plugs have not aided the coating in resisting deterioration. Because of the reversed movements, possibly both ends of joints should be plugged.

No excessive corrosion was observed in the joints without a preservative. So far, there has been no evidence of the existence of brine corrosion in the test track.

Final conclusions will be deferred until more information is developed.

Acknowledgement

The Association is grateful to the Illinois Central for its contribution in conducting the service tests and extends its appreciation to the participating suppliers and others who have rendered assistance.

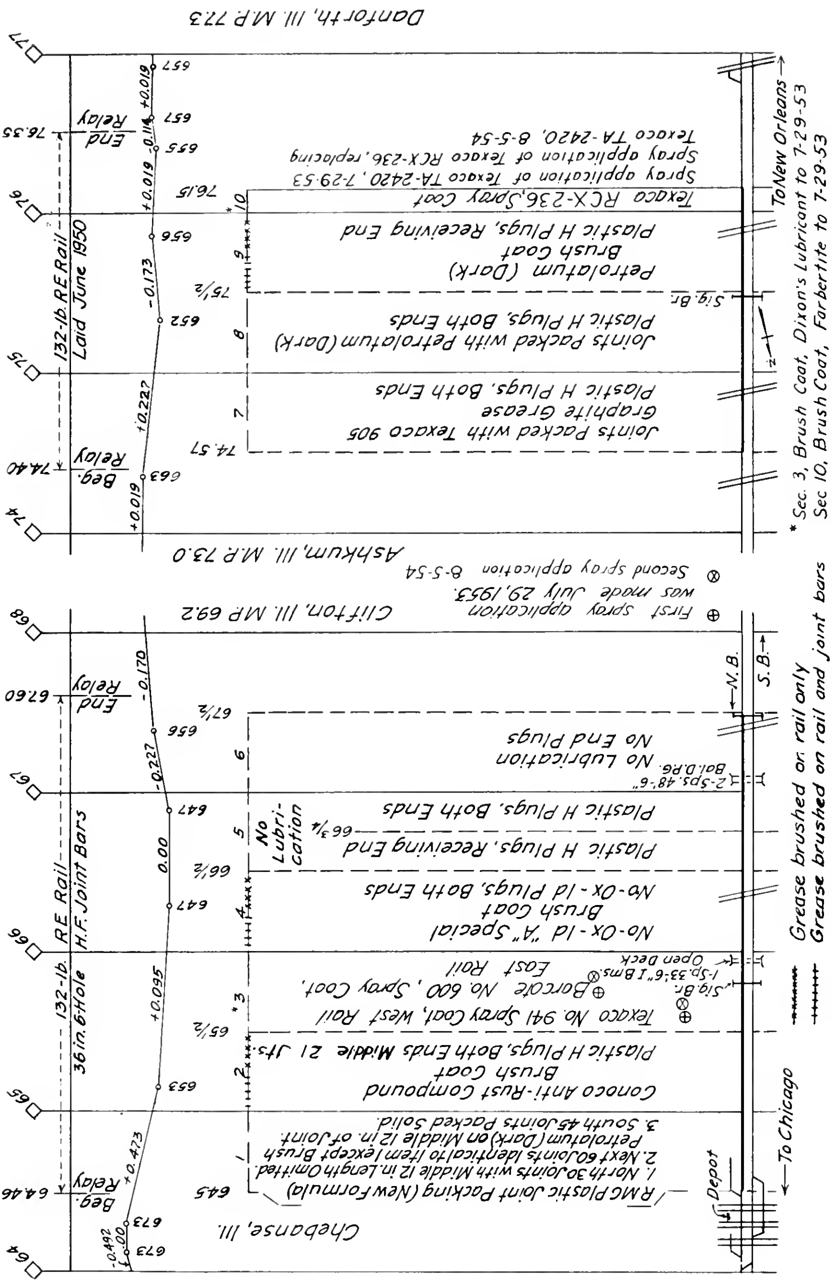


Fig. 1.—Rail Joint Lubrication Service Test in I.C.R.R. Northward Main Track Between Chebanse and Danforth, Ill.

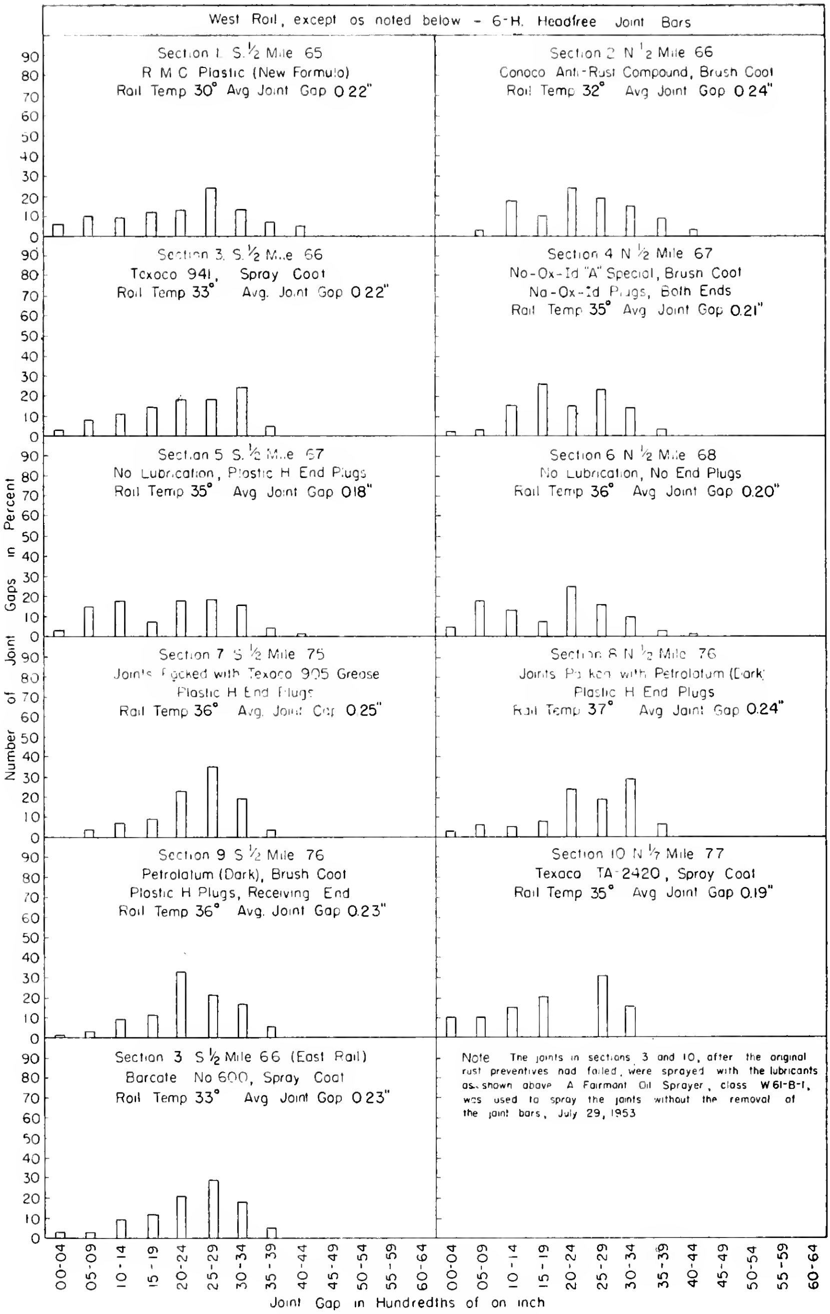


Fig 2 Joint Gap Measurements for Rail Joint Lubrication Test December 30, 1953.
I C R R Chebanse to Danforth, Ill

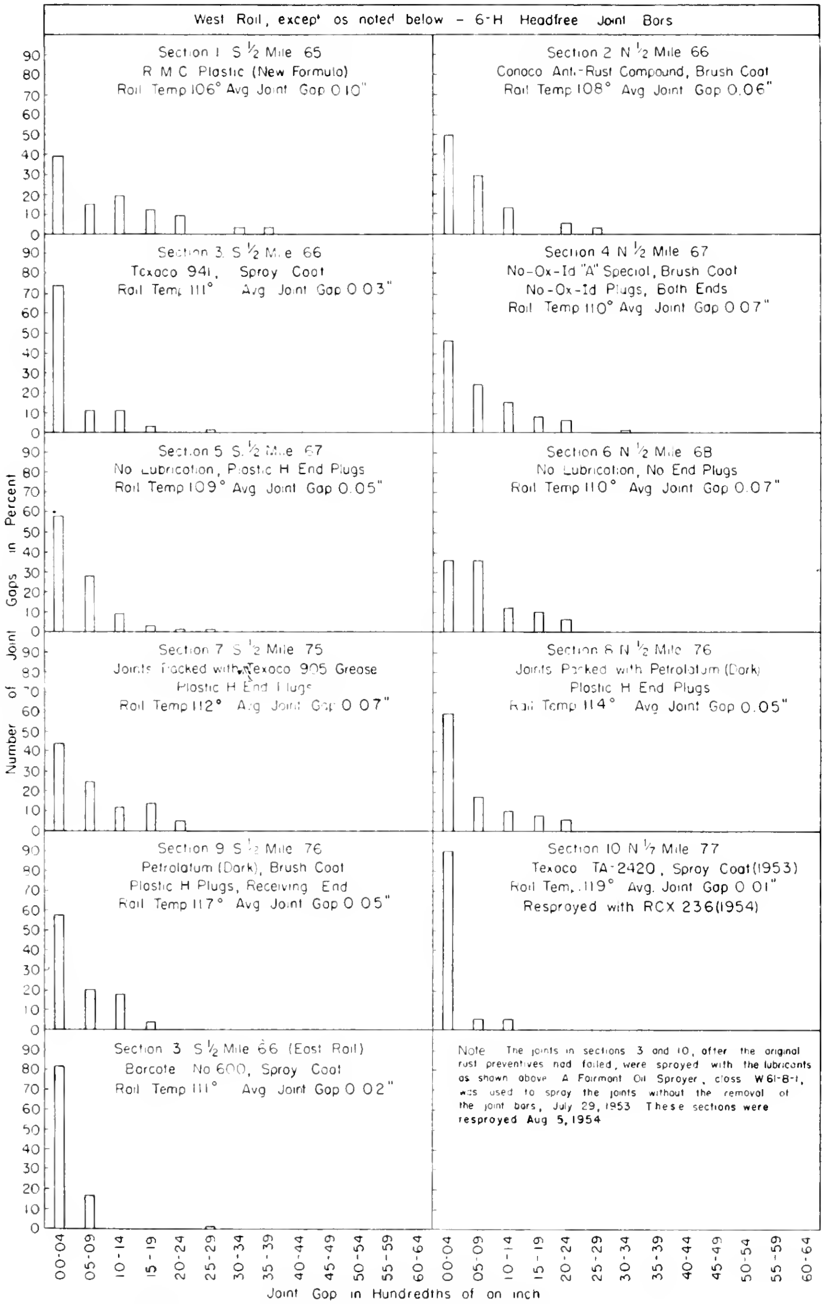
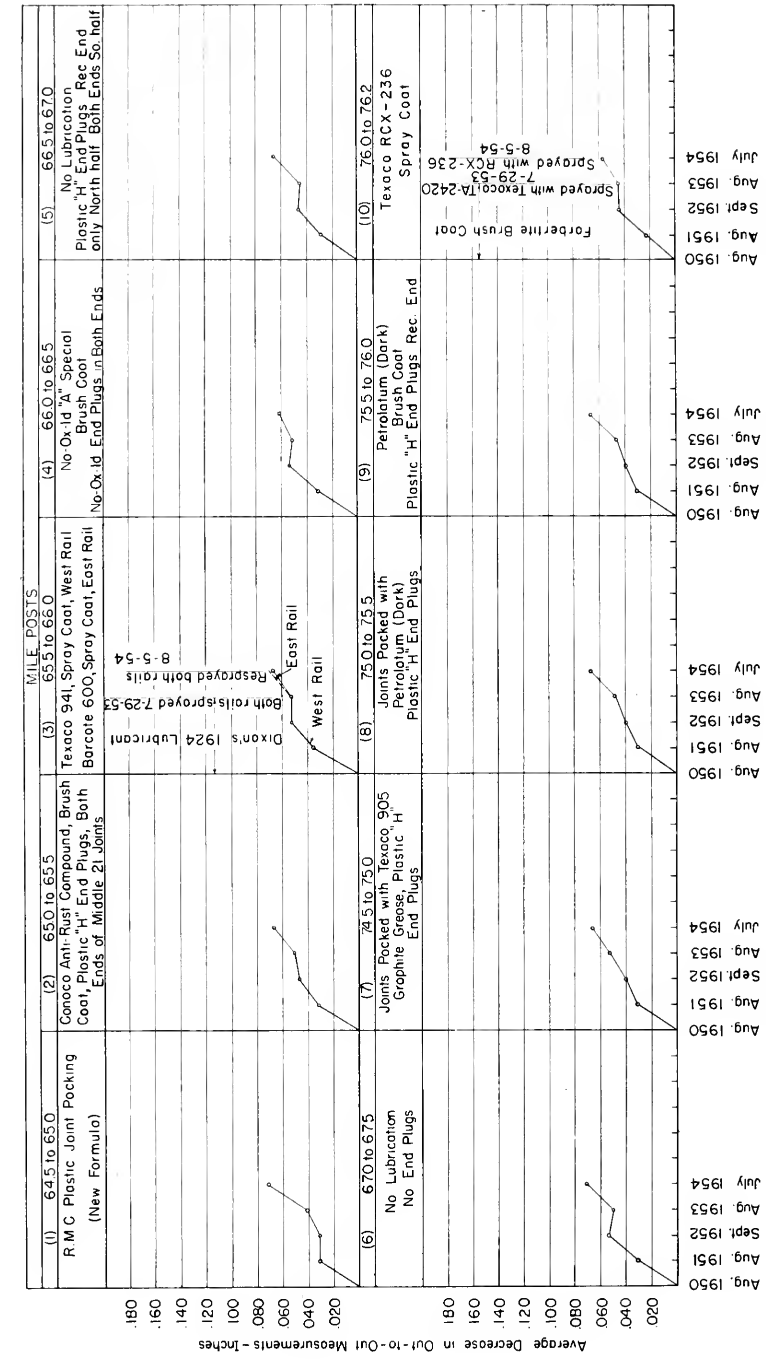


Fig 3 Joint Gap Measurements for Rail Joint Lubrication Test, July 23, 1954
I C R R Chebanse to Danforth, Ill

A



Note. Out-to-Out measurements taken at top and bottom of ends and middle of all joint bars in west rail, except as noted
Values shown are the mean of top and bottom of bars

Fig. 4 Average Pull-in of Joint Bars, I.C.R.R., Chebanse to Danforth, Illinois

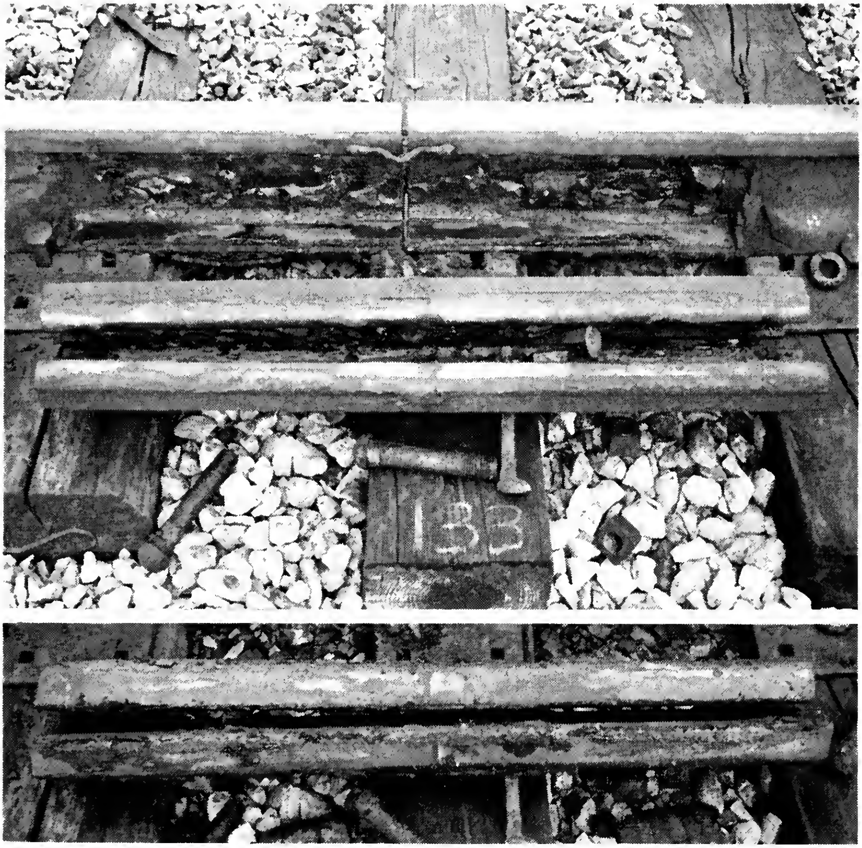


Fig. 5. South Portion Section 1. Joint packed solid with RMC Plastic Joint Packing (New formula)

Fig. 6. North Portion Section 2, Conoco Anti-Rust Compound (Brush coat on rail and bars)

Fig. 7. North Portion Section 2, Conoco Anti-Rust Compound with Plastic H Plugs in Both Ends (Brush coat on rail and bars)

Fig. 8. North Portion Section 4. No-Ox-Id "A" Special with No-Ox-Id Plugs in Both Ends (Brush coat on rail and bars)

Fig. 9. South Portion Section 4, No-Ox-Id "A" Special with No-Ox-Id Plugs in Both Ends (Brush coat on rail only)

Fig. 10. South Portion Section 5, No Lubrication (Plastic E plugs both ends)

Fig. 11. Section 6, No Lubrication or End Plugs

Fig. 12. Section [illegible] Packed [illegible] No. [illegible] Plastic H End P[illegible]

Fig. 13. Section 8, Packed with Petrolatum (Dark) and Plastic H End Plugs

Fig. 14. South Portion Section 9, Petrolatum (Dark) (Brush coat on rail only and Plastic H receiving end plugs)

Fig. 15. West Rail Section 3, Spray Coat of Texaco No. 941 after One Year of Service

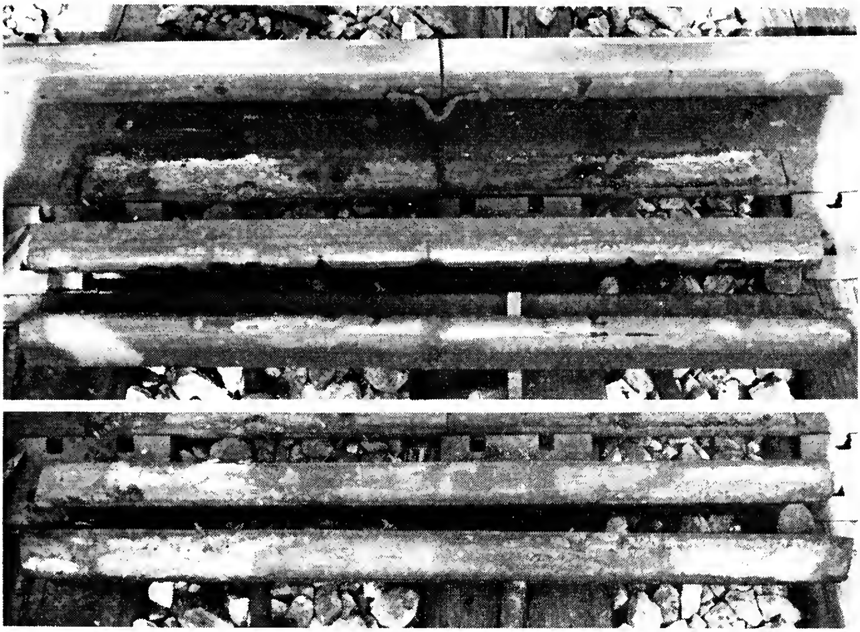


Fig. 16. East Rail Section [illegible], Spray Coat of Leadolene Bareote No. 600 after One Year of Service

Fig. 17. Section 10, Spray Coat of Texaco TA-2420 after One Year of Service

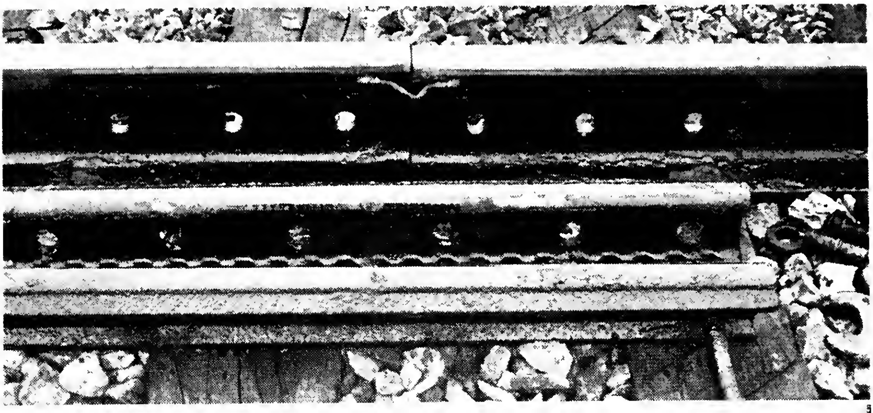


Fig. 18. West Rail Section 6, Second Spray Coat of Texaco [illegible] (One hour after application)

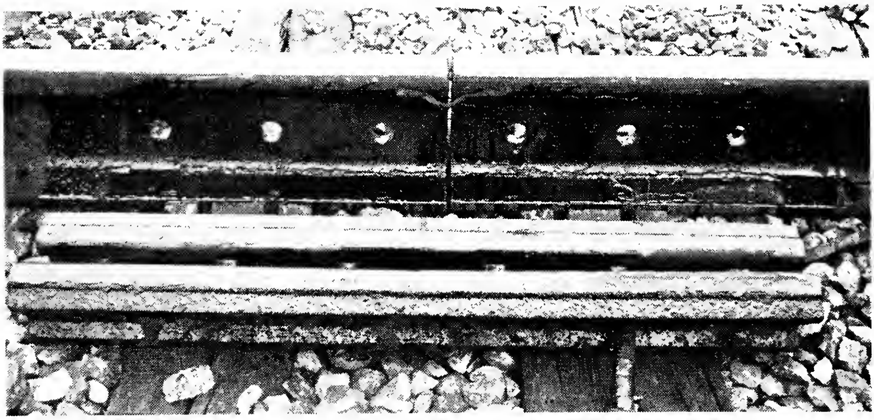


Fig. 19. East Rail Section 7, Second Spray Coat of [illegible] No. 600 ([illegible]0 min after application)

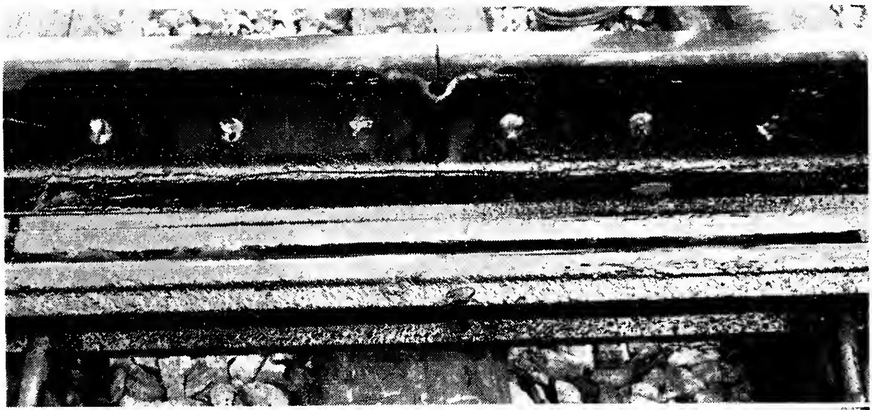


Fig. 20. Section 10, Spray Coat of Texaco RCX-256 (50 min after application)

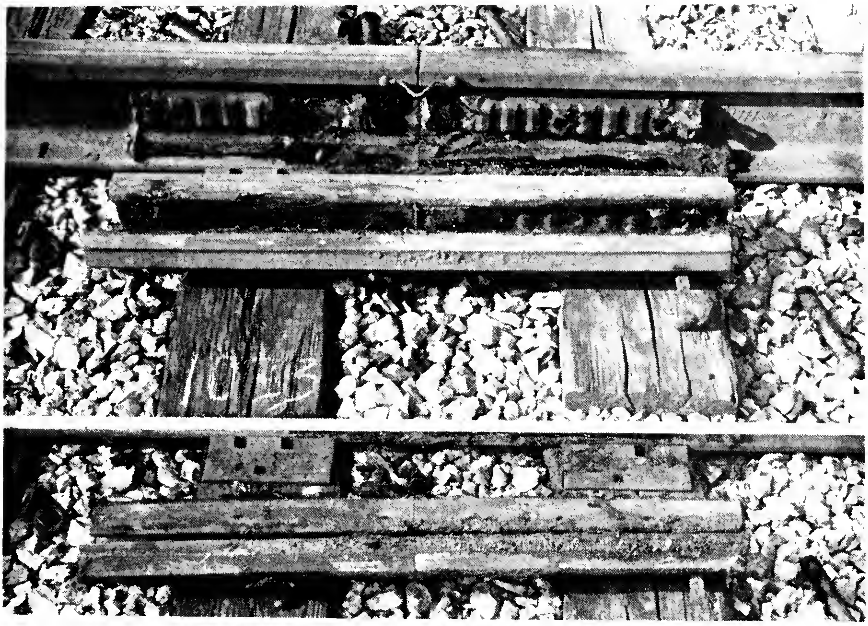


Fig. 21. 131 RE H. C. Rail Joint Packed Solid with RMC Plastic Joint Packing [illegible] After [illegible] in the Westward Main of the Burlington Railroad near Earlville, Ill.

Fig. 22. 131 RE H. C. Rail Joint with Brush Coat of Petrolatum (Dark) After 4 years' Service in the Westward Main of the Burlington Railroad near Earlville, Ill.

Report on Assignment 9

Critical Review of the Subject of Speed on Curves as Affected by Present-Day Equipment

Collaborating with the AAR Joint Committee on Relation Between Track and Equipment

W. R. Bjorklund (chairman, subcommittee), L. L. Adams, D. B. Barge, Jr., F. J. Bishop, M. C. Bitner, T. Fred Burris, H. F. Busch, W. E. Cornell, H. W. Cox, Jr., L. E. Donovan, J. W. Fulmer, D. C. Hastings, E. R. Murphy, W. N. Myers, J. S. Parsons, Troy West.

This is a progress report, submitted as information.

The test data for this assignment has been reported by the Joint Committee on Relation Between Track and Equipment of the Engineering and Mechanical Divisions, AAR, in AREA Bulletin 516, page 125. Experimental information indicates that equilibrium elevation is a function of the bearing points of the wheels on the rail rather than the conventional "G" which equals the "gage of the track of 4 ft 8½ in". The experimental information further indicates that the 3-in unbalanced elevation now published in the AREA Manual should be continued in effect for standard heavy-weight passenger equipment, but that newer passenger equipment which utilizes large center bearings, swing hangers, and roll stabilizers can negotiate curves comfortably at more than a 3-in unbalanced elevation because of the lesser car body roll. We are continuing to study this problem and the data developed by the AAR.

The question of speed on transition curves and turnouts as affected by present-day equipment will be covered after recommendation has been decided upon for the simple curve.

Report on Assignment 10

Methods of Heat Treatment, Including Flame Hardening, of Bolted-Rail Frogs and Split Switches, Together with Methods of Repair by Welding

S. H. Poore (chairman, subcommittee), L. L. Adams, F. J. Bishop, M. C. Bitner, W. R. Bjorklund, J. C. Brennan, W. E. Cornell, P. H. Croft, K. E. Dunn, H. F. Fifield, W. E. Griffiths, V. C. Hanna, M. J. Hassan, A. E. Haywood, A. B. Hillman, J. W. Hopkins, C. H. Johnson, T. R. Klingel, R. E. Miller, E. R. Murphy, H. B. Orr, J. S. Parsons, C. E. Peterson, R. D. Simpson, T. R. Snodgrass, R. E. Tew.

Tests of Welding Techniques for Repair and Serviceability of Four Metallurgies of Rail Steel in Simulated Units of Bolted Rail Crossing Flangeway Intersections

This is a progress report, submitted as information.

Foreword

In this phase of the investigation, information will be obtained from laboratory and field tests of welding on flame-hardened, heat-treated and control-cooled carbon-steel rails and the low-alloy, chrome-vanadium rail for determining the best methods of building up battered crossing corners and joints. The welding techniques selected for maintaining the simulated crossing units in track will be correlated with the serviceability of the units in the field. It is expected that the results of these tests will be used for preparing (1) a manual on the preferred welding techniques for good maintenance of special trackwork made of various metallurgies and heat treatment of rail steel, (2) specifications for flame hardening, and (3) determining the best method of heat treatment for maximum serviceability.

Because it was not practical to conduct these tests with full-size crossings, it was decided to use simulated crossing intersections of bolted construction, three-rail type, in one side of the track only.

Fabrication of Test Units

Six manufacturers, working as a group and collaborating with the subcommittee, furnished three 39-ft panels of 8 units of flangeway intersections. Each panel is of the same construction as shown in Fig. 1. Each manufacturer obtained two 132 RE rails from the same heat, which had carbon content above the median of the specified carbon range, or more commonly called blue-end rail. Each manufacturer prepared three sets of running and easer rails without charge, and, in addition, the Pettibone Mulliken Corporation prepared the design, furnished the balance of the material, and fabricated the three panels at actual cost without profit.

Three frog manufacturers furnished the flame-hardened rails: Pettibone Mulliken Corporation; Trackwork Division, Taylor–Wharton Iron & Steel Co. (formerly Weir–Kilby Corporation); and the Ramapo Ajax Division, American Brake Shoe Company. The Pettibone Mulliken and Weir–Kilby methods of flame hardening were similar in that each used dehydrated compressed air as the quenching medium. Ramapo's method utilized ambient air as a quench, followed by a water bath about 10 in behind the oxyacetylene flame after the rail had dropped below the critical temperature. Three other manufacturers furnished the heat-treated rails: Bethlehem Steel Company, Steelton; Cleveland Frog & Crossing Co.; and United States Steel Corporation, Johnstown Works. U.S.S. used in its heat-treating process a water quench, and the other two frog manufacturers used oil as the quenching medium. The control-cooled rail units were also made of rails of the same heat. In this test it was also desired to include the low-alloy, chrome-vanadium steel to determine its suitability for bolted rail crossing construction and to investigate repair by welding. The Norfolk and Western Railway very kindly agreed to furnish one of its 132 RE C–V rails which had carried 90 million gross tons of traffic as the outer rail of a 6-deg curve. This was the only RE rail section of chrome-vanadium steel available at that time. C–V rail is a self-hardening rail and has a Brinell hardness of about 350 in the as-rolled condition. C–V rail is being tested in curves for the primary purpose of retarding the formation of shelly failures in the outer rail of curves. The head wear on the C–V rail was so little that it was not necessary to build up the rail surface to meet adjoining units of new carbon-steel rail. A photographic view of one of the test panels is presented in Fig. 2.

Installation of Test Panels

The Chicago, Milwaukee, St. Paul & Pacific Railroad very kindly agreed to install the three 39-ft test panels in its main track No. 3, Mannheim, Ill., where the previous tests with manganese steel frog points had been conducted. Track No. 3 carries about 15 million gross tons per annum of slow-speed freight traffic enroute to the new hump yard at Bensenville, Ill. All trains are hauled by diesel power, and there is no passenger traffic on track No. 3. The grade of the track is about level.

Because of the short rails and their possibility of drooping at the flangeway intersections, the only accurate way to determine the batter was to measure the change in rail height. This made it necessary to use individual tie plates instead of a continuous base plate. In addition, this change will also promote better tamping. To provide the test units with better support because of the impacts at the flangeway intersections, new or good used 7-in by 9-in by 9 ft creosoted oak ties were used to replace the 8-ft 6-in ties, all of the extra length being placed under the south rail in which the test units were placed. The three test panels were separated by one 39-ft rail length, and 8 rail lengths of the north rail were also relaid with new 132 RE rail and 6-hole joint bars.

Construction was started on April 12, 1954, and completed by noon of April 15, 1954, for the inspection by the subcommittee that afternoon. The old ballast was removed and replaced with Janesville processed gravel. The 1⅜-in frog bolts were tightened with a Nordberg power track wrench. Two views of the construction work are shown in Fig. 3.

Laboratory Hardness Readings

Brinell hardness readings were taken on sections cut from short pieces of rail furnished to the AAR laboratory to represent the rail used in the test units. Some specimen rails were not furnished for this purpose. These data are presented in graphical form in Figs. 4 and 5. In the two figures the open circles indicate that the hardness readings were determined with a Brinell hardness tester, and the solid dots were taken with a Rockwell hardness tester. In the right portion of Fig. 5, Tukon micro-hardness readings were taken below the running surface of the used C–V rail to find the point of maximum cold working. The highest Brinell reading of 382 was obtained 0.6 mm to 0.8 mm below the surface, as compared with 361 on top of the rail. There had been little cold working of the C–V rail, as the hardness on the field side of the rail ranged from BHN 356–359. The layer of hardened steel was much thinner on the Pettibone Mulliken flame-hardened specimen than that on the Weir–Kilby specimen (Fig. 5).

Service Test Measurements

The initial or base readings for rail batter and wear, and increase in hardness caused by cold working of the steel under traffic, were taken on top of the running rails of the 24 test units in the Pettibone Mulliken shop prior to installation in track. Both sets of readings were taken on the center line of the rail head at points 10 in from the ends of each unit and ¾ in from the nearest face of each flangeway, making 4 readings in each category for each unit. The "10-in" points will serve to determine the normal rail head wear and amount of cold working. Data for the points on the tread corners will be used to determine the batter and cold working of the rail surface. The Brinell hardness readings have been summarized in Table 1. A soft disk-type stone was used for grinding off the decarb and mill scale from the top and bottom of the rail at the locations of the measurements. It is possible that in some cases, particularly for the heat-treated rails, all of the decarb was not removed. It was not desired to grind so deep on the rail head as to set up a simulated batter condition. The heat-treated rails ranged from an average of BHN 325 for one manufacturer to 339 for another. The corresponding figures for the flame-hardened specimens ranged from a BHN of 309 to 354, the Ramapo specimens being the hardest. It will be of interest to observe in Table 1 that the used C–V rail hardness on top was about the same as on the field side of the rail head. The King portable hardness tester was used in taking the initial measurements on the running rails before assembly of the crossing units.

(Text continued on page 888)

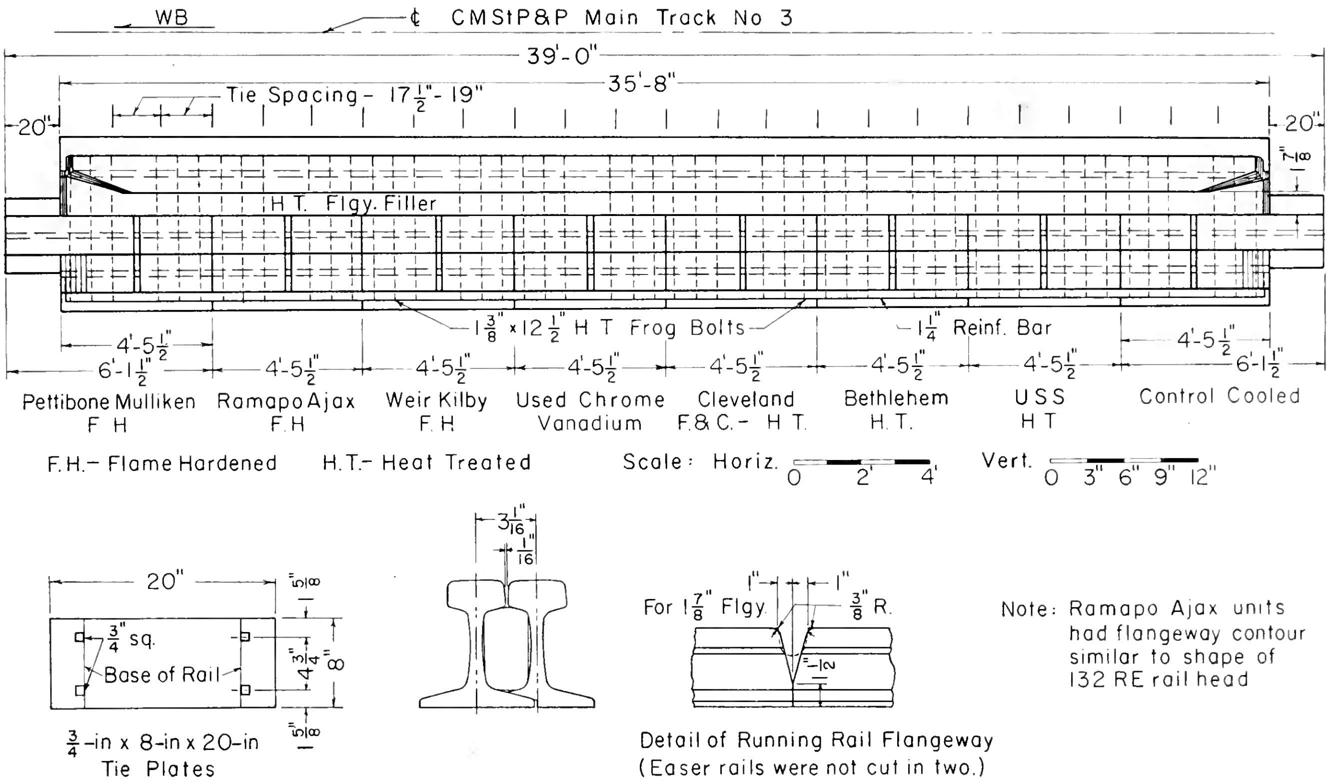
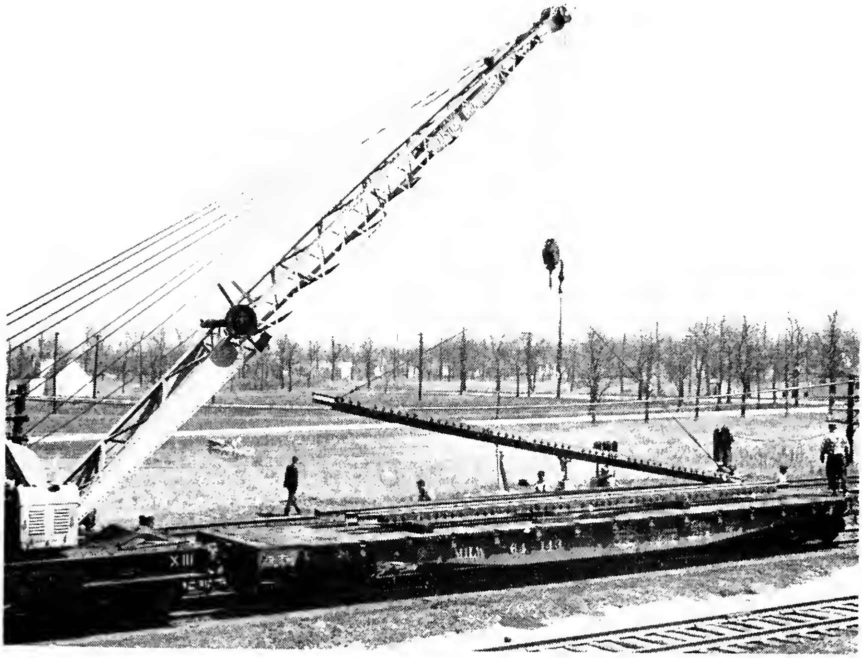


Fig. 1. Plan of One Panel of Eight Units of Simulated 132 RE Bolted Rail Crossing Flangeway Intersections at Mannheim, Illinois.

Fig. 2. View of Center Test Panel After 3 1/2 Months' Traffic (The first flangeway in the foreground is in the unit with unhardened control cooled rail).



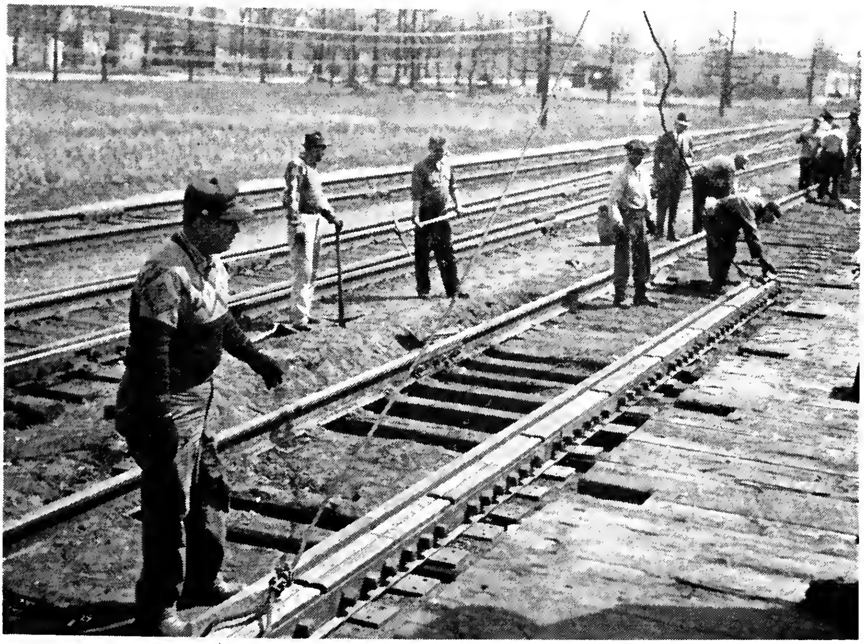
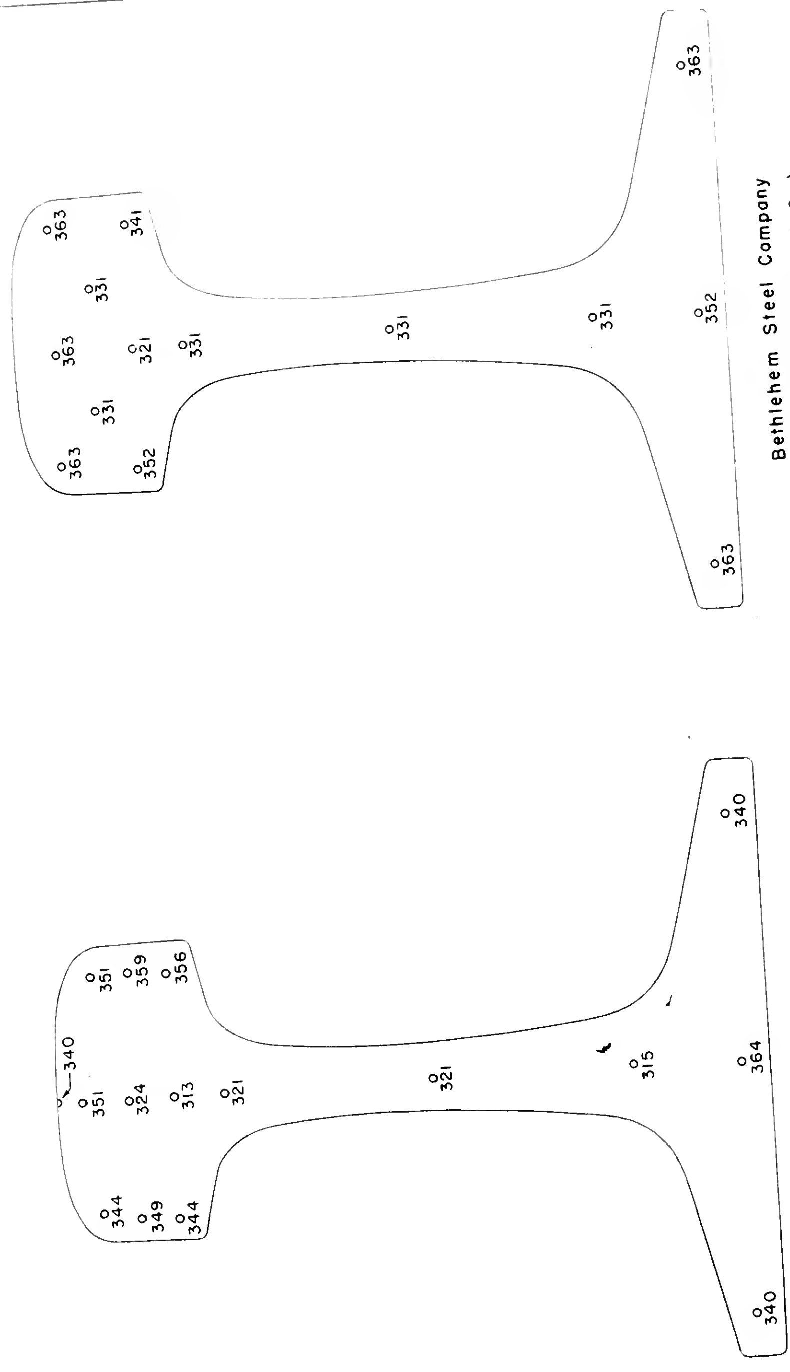


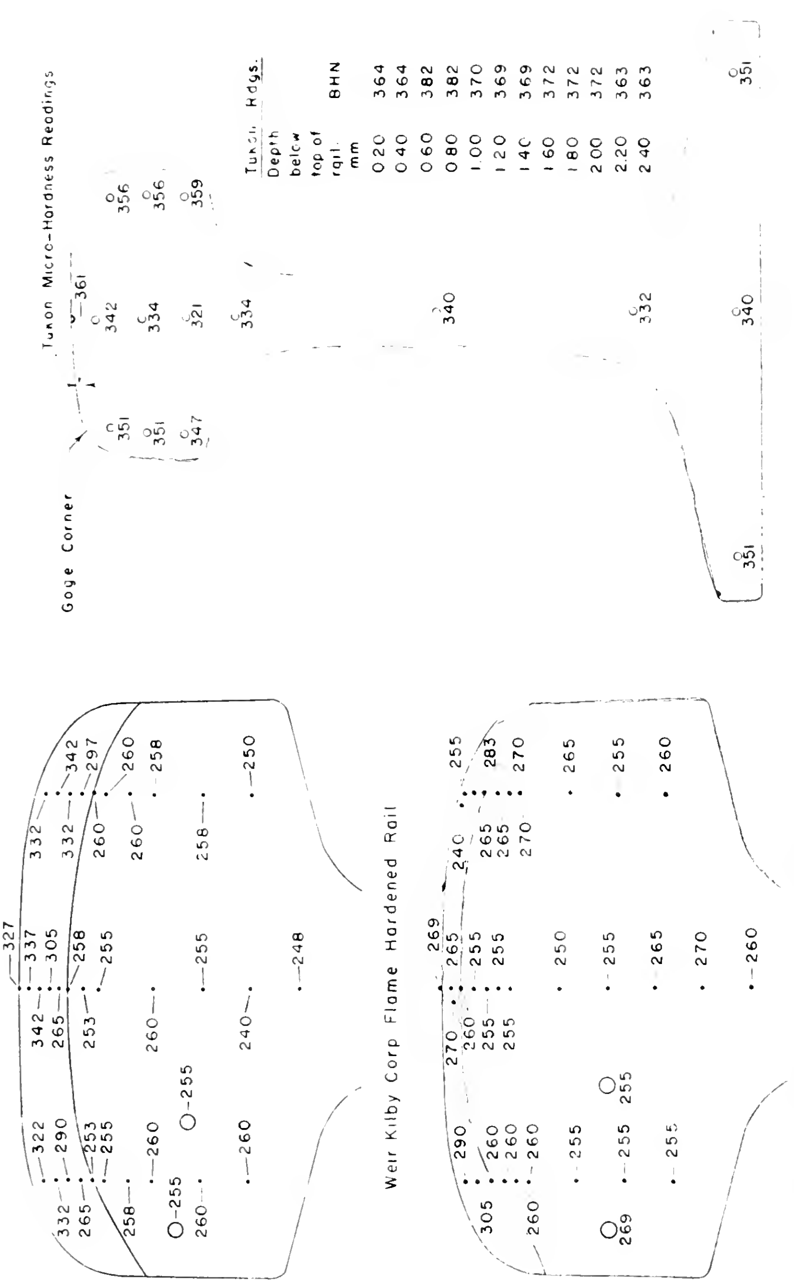
Fig. 3. Setting in Place the West Test Panel Before Renewing the Ties and Ballast



Bethlehem Steel Company
(Data furnished by B. S. Co.)

Cleveland Frog & Crossing Company

Fig. 4. Brinell Hardness Readings of Heat Treated Rails



Pettibone Mulliken Corp. Flame Hardened Rail

Used Chrome-Vanadium Rail

Fig. 5. Brinell Hardness Readings of Flame Hardened and C-V Rails

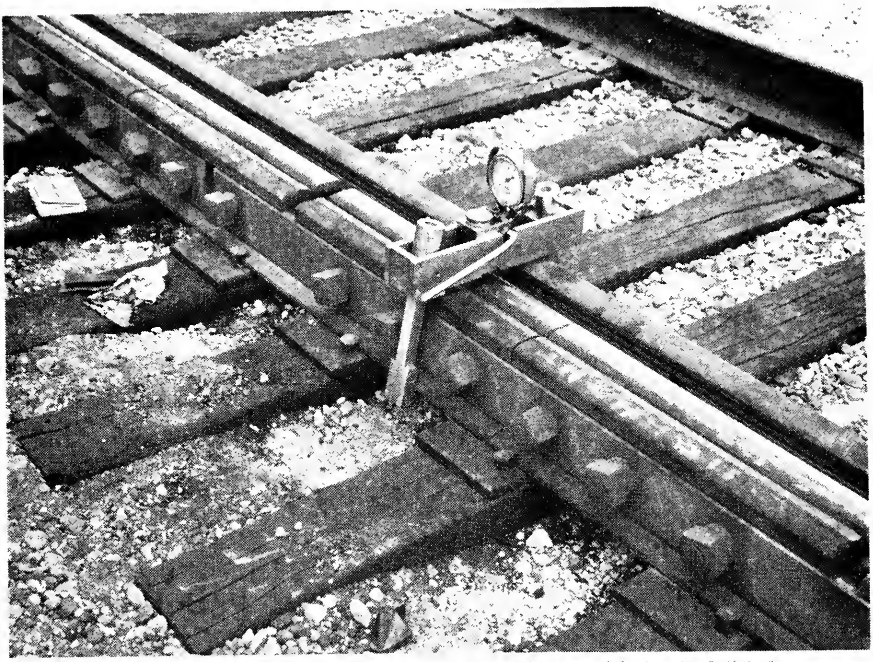


Fig. 6. King Portable Brinell Tester for Measuring the Hardness of the Running Rail Surface

Fig. 7. Vertical Rail Height Gage for Determining Rail Head Wear and Batter

TABLE I. BRINELL HARDNESS READINGS TAKEN ON TOP OF RUNNING RAILS OF EACH UNIT IN THREE PANELS OF SIMULATED CROSSING INTERSECTIONS PRIOR TO INSTALLATION IN TRACK AT MANNHEIM, ILLINOIS

Panel	Description of Unit	BHN (3000 kg)						
		West End	Rec. Corner	Lv. Corner	East End	Avg.	Range Low	Range High
Heat Treated Rail								
West	United States	311	344	347	309	328	309	347
Center	Steel	338	323	342	337	335	323	342
East	Corporation	309	311	332	300	313	300	332
						325	300	347
West	Bethlehem	344	327	337	337	336	327	344
Center	Steel	332	340	340	342	338	332	342
East	Company	364	342	324	342	343	324	364
						339	324	364
West	Cleveland Frog	329	340	344	349	340	329	349
Center	and Crossing	334	332	329	337	333	329	337
East	Company	323	337	334	335	332	323	337
						335	323	349
Flame Hardened Rail								
West	Weir	319	302	321	337	320	302	337
Center	Kilby	323	321	324	319	322	319	324
East	Corporation	302	290	309	304	301	290	309
						314	290	337
West	Ramapo Ajax Div.	361	359	351	359	358	351	361
Center	American Brake	335	368	351	340	348	335	368
East	Shoe Company	349	366	364	340	355	340	366
						354	335	368
West	Pettibone -	313	307	309	311	310	307	313
Center	Mulliken	319	315	324	306	316	306	324
East	Corporation	311	311	302	282	302	282	311
						309	282	324
Other Rails								
West	C.C. Blue End Rail as rolled	255	249	242	258	251	242	258
Center	(C. 0.78, Mn. 0.82, Ph. 0.011,	252	254	255	251	253	251	255
East	Sul. 0.036, Sil. 0.18)	247	245	255	244	248	244	255
						251	242	258
West	Used Chrome -	364	366	366	368	366	364	368
Center	Vanadium	361	359	361	364	361	359	364
East	Rail	361	366	366	361	364	361	366
						364	359	368
West	Used C-V Rail	368	371	368	366	368	366	371
Center	Hardness on	364	359	366	371	365	359	371
East	Side of Head	368	368	364	359	365	359	368
						366	359	371

Brinell hardness for 7 flangewsy fillers of center panel ranged from 259 to 321, averaging 282.

For taking hardness readings on the running rails in the field, a special clamp for the King tester was made of 18–8 stainless steel. This equipment is shown in Fig. 6. The rail height measurement gage was adapted from one of the gages formerly used for measuring pull-in of the joint bars, as shown in Fig. 7. Since the photograph was taken, a pocket level has been attached transversely to the gage frame to aid in plumbing it. Because of the small amount of tonnage that had passed over the test panels by September 1954, publication of the initial field measurements will be deferred until next year.

Laboratory Welding Experiments

In order to determine the best welding procedures for building up the batter on the tread corners, tests will be conducted in the laboratory on 8 rails representative of the variations in rails of the test panels. These rails, varying in length from 10 ft 4 in to 18 ft 4 in, have been received at the laboratory.

Questionnaires as to recommended welding procedures have been furnished to three nationally known welding companies, the six cooperating frog manufacturers, and one railroad. As soon as all replies have been received the experimental work will be conducted. All of the welds will be examined metallurgically. The best procedures will be selected for maintenance of the test units. If there are as many as three good welding techniques for repairing a given unit, each of three units can be repaired with a different method. This will provide an opporunity for comparing the three methods in the field. Later changes in the field may be made if some of the welding procedures are not satisfactory under traffic.

Acknowledgement

The Association extends its appreciation to the Milwaukee Road for its splendid cooperation and assistance in making an excellent installation of the test panels, to the six suppliers, the N&W, and to those who will render assistance in conducting the welding tests.

Report of Committee 4—Rail

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H. F. Whitmore
R. P. Winton
Edward Wise, Jr.
J. E. Yewell

Committee

* Died June 29, 1954.
(E) Member Emeritus.

To the American Railway Engineering Association:

Your committee reports on the following subjects:

The Committee on Rail,
C. J. Code, *Chairman.*

AREA Bulletin 521, February 1955.

MEMOIR

Carleton Bennett Harveson

Carleton Bennett Harveson, chief engineer maintenance, Baltimore & Ohio Railroad, and a member of the American Railway Engineering Association since 1926, died on June 29, 1954. Mr. Harveson was born at Jacksonville, N. J., December 18, 1885, and attended Philadelphia Central High School and Bucknell College. He entered the service of the Philadelphia and Reading Railway in 1905 as a draftsman and advanced progressively to the position of supervisor of track. Furloughed for military service with the outbreak of World War I, he was in foreign service from December 1917 until June 1919, advancing from First Lieutenant to Major of Engineers. He returned to the Reading in July 1919 as a supervisor of track.

In 1922, Mr. Harveson was appointed division engineer on the Baltimore & Ohio at Philadelphia, Pa., advancing to engineer maintenance of way of the Eastern Region in June 1936. In 1944 he was made chief engineer maintenance, in which capacity he remained until his death.

During his membership in the Association, Mr. Harveson was a member of Committee 1—Roadway and Ballast, in 1928, and a member of Committee 4—Rail, from 1944 until the time of his death.

He is survived by his widow, Bertha E. Wilson Harveson, whom he married in 1921, a son, Richard, and four grandchildren.

Mr. Harveson was a competent executive and a man of vision and imagination to all who knew him. He had a fine personality, was a keen sportsman, and had a great capacity for friendship. As a result, he had many real friends in all walks of life, who feel a deep loss in his death.

Report on Assignment 1

Revision of Manual

B. R. Meyers (chairman, subcommittee), C. J. Code, E. L. Anderson, F. W. Biltz, W. J. Burton, L. S. Crane, C. J. Geyer, J. L. Gressitt, R. L. Groover, W. H. Hobbs, C. C. Lathey, H. S. Loeffler, Ray McBrian, L. T. Nuckols, E. E. Oviatt, R. E. Patterson, G. L. P. Plow, R. B. Rhode, J. C. Ryan, E. F. Salisbury, S. H. Shepley, A. A. Shillander, G. L. Smith, J. S. Wearn, H. F. Whitmore, Edward Wise, Jr.

The following revisions are submitted with the recommendation that they be adopted and published in the Manual:

Pages 4–1–6.2 to 4–1–13, incl.

JOINT BARS AND ASSEMBLIES

Page 4–1–12.1—make following changes in dimensions shown for 140 RE joint bar, Fig. 7a, so that same will conform to information shown for other joint bars:

Add dimension of 5/8" for bar web thickness.

Add dimension of 2.69" to show distance from bottom of bar to neutral axis of bar.

Add dimension of 2.50" to show distance from neutral axis of bar to top of bar.

Add dimension of 3.25" to show distance from base of rail to neutral axis of joint bar.

Remove dimension of 3.37" which represents distance from base of rail to neutral axis of rail and is confusing on this drawing.

Correct table of Physical Properties for Standard AREA Bar Punchings to read as follows:

Physical Properties	*One Bar*	*Two Bars*
Moment of Inertia in^4	16.25	32.5
Section Modulus — Above n.a. in^3	6.50	13.0
Section Modulus — Below n.a. in^3	6.04	12.1
Area sq in	6.00	12.00
Net weight, 24-in length, lb	40.0	80.1
Net weight, 36-in length, lb	60.1	120.1

Pages 4–3–1 to 4–3–14, incl.

RAIL RECORD FORMS

Page 4–3–12. Revise Form 402–L to obtain data on the mileage of detector car testing and number of detected defects separately as between railroad owned and leased cars and between inductance and magnetic-type cars. The revised form is presented herewith.

Adopt new Form 402–M (presented herewith) to obtain data now secured by letter inquiry, and insert as page 4–3–12.1.

Form 402-L

REPORT OF ANNUAL PROGRESSIVE TYPE HEAD FAILURES IN RAIL OF ALL AGES, MADE BY ALL PROCESSES

Date________________, 19__

Director of Engineering Research, Eng. Div.
Association of American Railroads
3140 So. Federal Street
Chicago 16, Illinois

Dear Sir:

The____ Railroad reports the following for the year January 1, 19__ to December 21, 19__.

Service Failures

Transverse Fissures	____________
All other Transverse Defects including Compound Fissures and Detail Fractures	____________
Engine Burn Fractures	____________

Detected Failures	By Detector Cars* RR Owned	By Detector Cars* Leased
Transverse Fissures verified by breaking	________	________
All Transverse Defects including Unverified Transverse Fissures, Compound Fissures and Detail Fractures	________	________
Engine Burn Fractures	________	________
Miles Tested by Detector Cars	________	________

*Note: Show data separately for inductance or magnetic-type cars, and designate by (I) or (M), respectively.

This report covers our entire system____

This report covers only the following roads__________________________________

Equivalent single main-track miles of report territory________________________

Yours very truly,

Name__________________________

Official Title____________________

Address________________________

Form 402-M

ANNUAL REPORT OF RAIL FAILURES IN THE WEB WITHIN
JOINT BAR LIMITS IN RAIL OF 100 LB AND ALL HEAVIER SECTIONS
(For the year ending December 31, 19)

RAILROAD

Rail	Rail Rolled Previous to 1937				Rail Rolled in 1937 and after			
Sec-	Detected Failures		Service Failures		Detected Failures		Service Failures	
tion	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other

Number of joints inspected during the year by defect detecting instruments or equipment, including the supersonic type _______________.

Add in Miscellaneous Part the following additional Recommended Mill Practice for Rails for Butt Welding:

MILL PRACTICE FOR RAILS FOR BUTT WELDING

The following recommended practices will serve as a guide for ordering rails for butt welding and may be used as a supplement to Specifications for Open-Hearth Steel Rails:

1. General

Except for the provisions herein set forth, all rails for butt welding purposes will be processed in accordance with the latest AREA rail specifications, and will be furnished in standard 39-ft lengths, control cooled.

2. Purchaser's Order

a. The purchaser's order shall specify tonnage rather than the numerical quantity of rails.

b. The purchaser's order shall specify, in tons, the amount of right-hand drilling, left-hand drilling, and blank rails desired. Right hand or left hand end of rail will be determined by facing side of rail on which brand is stamped.

c. In order to provide the desired tonnage in rails generally considered as suitable for butt welding, it is necessary to produce enough total tonnage against the purchaser's order to provide for the exceptions listed in Art. 3.

3. Application of Rail by the Manufacturer

a. Unless otherwise specified, the "A" rails and those classified as "X-Rayls" and No. 2 rails will not be applied against the tonnage specified for butt welding.

b. Unless otherwise specified, short rails (rails less than 39 ft in length) will not be applied against the tonnage specified for butt welding.

c. It is understood that the rails not applied against the tonnage specified for butt welding will be accepted by the purchaser under the provisions in Art. 4, Par. b, d and e.

4. Drilling

a. When specified by the purchaser, rails drilled in the right- or left-hand end with the opposite end undrilled, will be furnished.

b. When right and left-hand drilling is specified, the excess of any one end drilling will be applied against the order.

c. When specified by the purchaser, blank rails (rails with both ends undrilled) will be furnished.

d. Unless otherwise specified, "A" rails, short rails and "X-Rayls" will be drilled on both ends.

e. Rails classified as No. 2 on the inspection beds, whether blank or right or left-hand drilling, will be applied without being returned to the Finishing Department for drilling.

5. Rail End Finishing

a. All rails, whether hot sawed, milled or ground to length, will be furnished with end squareness in accordance with the latest AREA rail specifications.

b. When end hardening is specified, right or left-hand rails will be end hardened and chamfered on the drilled end only and will be hot stamped "CH".

c. Blank rails will not be end hardened or chamfered at either end. (When blank rails are ordered along with end-hardened rails, they may also be hot stamped "CH".)

6. Classification Markings

No rails furnished for butt welding will carry any classification stamping or painting on the undrilled end faces. Blank rails will carry the classification paint marking on the top of the head, on one end only, at least 3 ft from the end.

7. Loading

Insofar as practicable, all rails shipped for butt welding will be loaded separately from rails supplied for bolted track.

Report on Assignment 2

Conditions Affecting Service Life of Rail, Causes of Rail Failures and Defects

In Collaboration with AISI Technical Committee on Rail and Joint Bars

C. J. Code (chairman, subcommittee), B. R. Meyers, C. B. Bronson, L. S. Crane, W. J. Cruse, R. A. Emerson, J. L. Gressitt, J. C. Jacobs, K. K. Kessler, Ray McBrian, L. T. Nuckols, Embert Osland, W. C. Perkins, G. L. Smith, R. P. Winton.

The research work sponsored by this committee at the University of Illinois and previously covered under the heading "Transverse Fissure Investigation" is being continued and is reported on by Professor R. E. Cramer, Appendix 2–a, under the title "Investigation of Failures in Control-Cooled Rails". It is the thought of the committee that this title more truly represents the work which is being carried on, since true transverse fissures in control-cooled rail are now virtually a thing of the past.

The investigation of shelly rail at the University of Illinois, which is also being carried on by Professor Cramer under the sponsorship of this committee, is included as an appendix in connection with the report on Assignment 8.

The committee has under discussion with the rail manufacturers a proposal to change the definition of so-called high-carbon rail, Art. 17, Par. (e) of the Rail specification, so as to include as blue end rails those which are above the mean percentage in both carbon and manganese. The manufacturers will submit a proposal on this subject, which will then be referred to the Rail committee for consideration.

Two other minor changes in the rail specification are under discussion with the rail manufacturers, as is the question of protective coating for track bolts.

The proposed specifications for 78-ft rail were submitted to the rail manufacturers at a meeting in September, and they are expected to submit a counter proposal.

Appendix 2–a

Investigation of Failures in Control-Cooled Railroad Rails

By R. E. Cramer

Research Associate Professor of Engineering Materials, University of Illinois

Organization and Acknowledgment

This investigation is financed equally by the Association of American Railroads and the American Iron and Steel Institute.

Student assistants D. L. Hare and W. B. Crum have worked for this investigation on a part-time basis during the past year.

Control-Cooled Rails Which Failed in Service

Since October 1, 1953, reports have been prepared on 49 failed control-cooled rails for the railroad engineers supplying the rails, and copies of the reports have been furnished the rail mills and the director of engineering research, AAR, for the Association's rail failure statistics.

Table 1 gives a summary of these failures. Table 2 lists each rail separately.

TABLE 1—SUMMARY OF RAIL FAILURES

Transverse fissures from shatter cracks	4
Transverse fissures from hot torn steel	16
Compound fissure from inclusion	1
Detail fractures from shelling	22
Fractures from welded engine burns	2
Engine burn fracture	1
Surface defect	1
Large head check	1
Web failure at stamped numbers	1
Total	49

Transverse Fissures from Shatter Cracks

Three of the transverse fissures from shatter cracks were in rails from the Algoma Mill rolled in March 1941, December 1942, and January 1949. The fourth transverse fissure from shatter cracks was produced at the Dominion Mill in August 1931. This was the first rolling of control-cooled rails made by any steel mill.

Transverse Fissures from Hot Torn Steel

The transverse fissures from hot torn steel were in rails from the following mills rolled in the years indicated.

Steelton—1935, 1936, 1937, 1940, 1941, 1942 (2), 1948, 1951.
Inland—1941, 1943, 1944 (2), 1946.
Lackawanna—1944, 1947.

Failed control-cooled rails have been examined by the writer for 14 years. In that time 150 failures from hot torn steel have been found, or an average of only about 11 per year. Fig. 1 shows a graph of the number of years these rails were in service before failure. This information may be of value in determining when new rails should be tested with a detector car.

TABLE 2—FAILED CONTROL-COOLED RAILS EXAMINED BETWEEN OCTOBER 1, 1953, AND OCTOBER 1, 1954

Source of Failed Rail	*Laboratory Failed Rail, Number*	*Size of Rail*	*Mill*	*Heat Number, Rail Letter, and Ingot No.*	*Date Rolled*	*Classification of Failure**
Virginian	806	131	Steelton	85092-B-13	11-1945	D.F. from shelling
Virginian	807	131	Steelton	85092-F-10	11-1945	D.F. from shelling
Virginian	808	131	Steelton	89253-C-4	6-1940	T.F. from hot torn steel
Virginian	809	131	Steelton	86170-B-6	4-1941	T.F. from hot torn steel
Virginian	810	131	Steelton	89084-B-2	6-1942	T.F. from hot torn steel
CB&Q	812	131	Inland	33687-C-7	9-1944	T.F. from hot torn steel
CRI&P	813	112	Inland	16392	3-1939	D.F. from shelling
CRI&P	814	112	Gary	------------	4-1939	D.F. from shelling
C&O	816	131	Inland	23302-D-12	11-1941	Fracture from welded E.B.
NYC&StL	817	131	Lackawanna	1059-A-20	1947	T.F. from hot torn steel
N&W	818	131	Steelton	83164-B-9	3-1942	T.F. from hot torn steel
RF&P	819	140	Steelton	88537-A-47	11-1948	T.F. from hot torn steel
CP	820	100	Algoma	2790-C-10	3-1941	T.F. from shatter crack
CP	821	100	Algoma	8374-D-7	12-1943	C.F. from inclusion
AT&SF	822	131	Inland	32418-C-17	1941	T.F. from hot torn steel
C&NW	823	112	Gary	34576-A-8	11-1943	Engine Burn Fracture
B&O	824	140	Steelton	88520-B-42	9-1951	T.F. from hot torn steel
CP	825	100	Algoma	2165-B-11	1-1949	T.F. from shatter crack
CB&Q	826	131	Inland	29931-F-11	9-1943	T.F. from hot torn steel
C&O	827	131	Steelton	85391-B-10	10-1935	D.F. from shelling
C&O	828	131	Steelton	87205-B-10	10-1953	T.F. from hot torn steel
C&O	829	131	Steelton	89064-C-15	2-1940	D.F. from shelling
C&O	830	131	Steelton	87321-C-5	9-1936	Fracture from welded E.B.
C&O	831	131	Steelton	86056-D-9	3-1946	D.F. from shelling

*D. F. = detail fracture· T.F. = transverse fissure· E.B. = engine burn C.F. = compound fissure.

(Table continued on next page)

TABLE 2—FAILED CONTROL-COOLED RAILS EXAMINED BETWEEN OCTOBER 1, 1953, AND OCTOBER 1, 1954 (Continued)

Source of Failed Rail	*Laboratory Failed Rail, Number*	*Size of Rail*	*Mill*	*Heat Number, Rail Letter, and Ingot No.*	*Date Rolled*	*Classification of Failure**
C&O	832	132	Lackawanna	12239–F–10	4–1950	D.F. from shelling
C&O	833	131	Gary	641268–D–9	1–1946	D.F. from shelling
C&O	834	131	Gary	46336–C–22	7–1936	Surface defect
C&O	835	131	Gary	89132–D–3	3–1942	Large head check
C&O	836	131	Gary	440577–A–12	11–1944	D.F. from shelling
C&O	837	131	Gary	971676–D–1	12–1946	D.F. from shelling
C&O	838	132	Inland	18091–E–4	1–1949	D.F. from shelling
C&O	839	131	Steelton	88262–B–6	9–1946	D.F. from shelling
CP	840	100	Dominion	8345–C–4	8–1931	T.F. from shatter crack
CMStP&P	841	131	Inland	30056–A–22	4–1944	T.F. from hot torn steel
B&O	842	131	E. Thomson	01E015–D–5	2–1946	D.F. from shelling
B&O	843	131	E. Thomson	10E134–E–6	2–1946	D.F. from shelling
CRI&P	844	112	Inland	13768	3–1938	D.F. from shelling
CRI&P	845	131	Inland	28813	8–1946	T.F. from hot torn steel
Southern	846	100	Tennessee	882051–H	4–1939	Web failure at stamped numbers
NYC&StL	847	131	Lackawanna	2131–A–20	3–1944	T.F. from hot torn steel
UP	848	131	Colorado	10613–E	1945	D.F. from shelling
UP	849	131	Colorado	1638–C	1945	D.F. from shelling
CP	850	100	Algoma	7593–F–6	2–1946	T.F. from shatter crack
CP	851	100	Algoma	1759–A–5	12–1942	D.F. from shelling
B&M	852	112	Lackawanna	30326–C–2	6–1945	D.F. from shelling
Virginian	853	131	Steelton	89129–F–20	3–1945	D.F. from shelling
Virginian	854	131	Steelton	8271–B–42	6–1949	D.F. from shelling
T&NO	855	112	Steelton	83175–C–9	12–1936	T.F. from hot torn steel
T&NO	856	112	Steelton	85468–B–5	12–1937	T.F. from hot torn steel

D.F. = detail fracture T.F. = transverse fissure E.B. = engine burn C.P. = compound fissure.

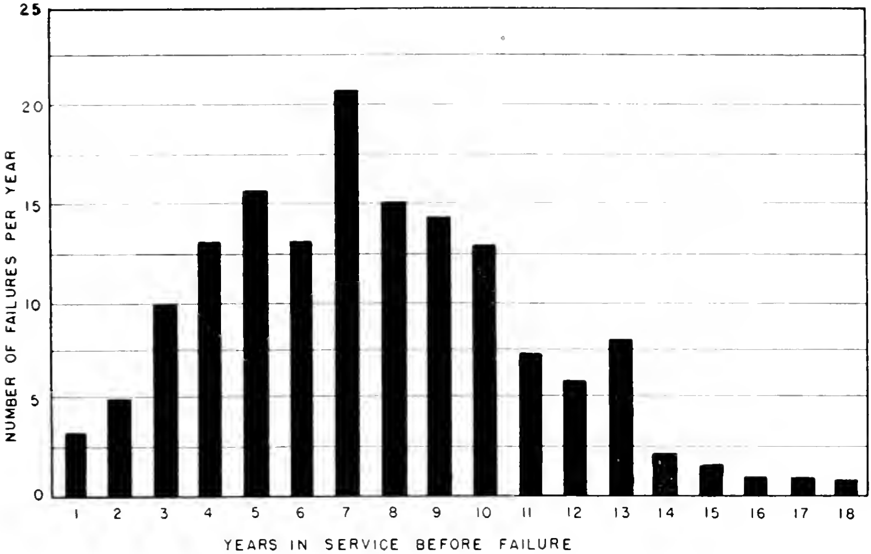


Fig. 1—Failure record of 150 hot torn steel rails, 1940–1954.

Compound Fissure From an Inclusion

The compound fissure from an inclusion was interesting because the inclusion was a very hard material which deformed when the rail was rolled. Fig. 2 shows both the fissure and a photomicrograph of the inclusion at 100× magnification. The nearly square indentations were made by a 136-deg diamond pyramid hardness tester. The average diamond penetration hardness of the rail steel was 300, which conversion charts show as Brinell hardness. The included material gave an average d.p.h. hardness of 1200, which is far above the Brinell range of hardness. The included material has not been identified.

Fractures from Welded Engine Burns

Fig. 3 shows etched sections of the two fractures from welded engine burns. Such failures usually start as horizontal cracks at the lower edge of the weld deposited metal, which appears white when the specimen is etched in ammonium persulfate solution.

The detailed fractures included in Table 1 will be discussed in another report on shelly rail studies.

Laboratory Tests of Tigerbraze Rail Bonds

Arrangements were made by G. M. Magee, director of engineering research, AAR, for the American Steel and Wire Company to furnish four specimens of a new type of electric brazed rail bond for laboratory tests. Reports of previous tests on torch-welded and thermit-welded rail bonds appear in the Proceedings, Vol. 51, 1950, pages 546 to 550, incl.

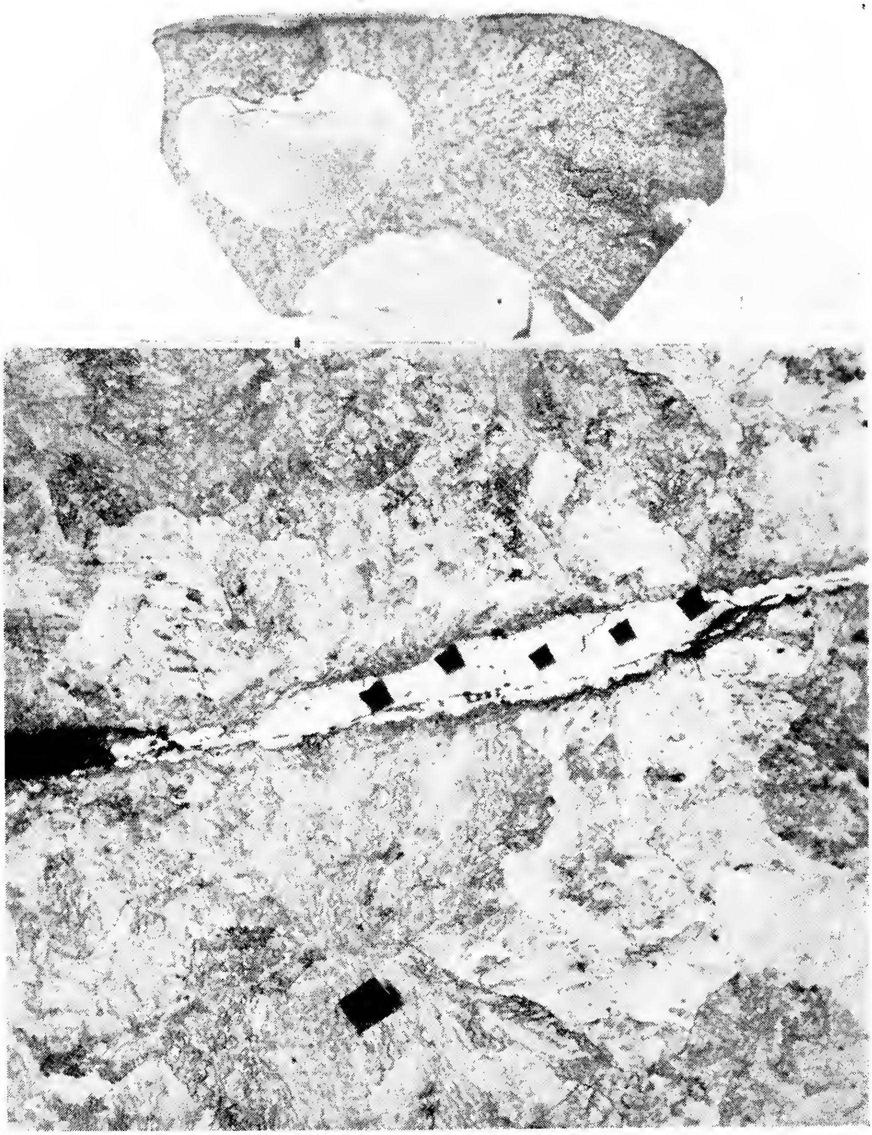


Fig. 2—Compound fissure from inclusion.

Top—Fracture showing fissure. Bottom—Photomicrograph showing inclusion and hardness tests. Magnification 100×. Etch 2 percent nital.

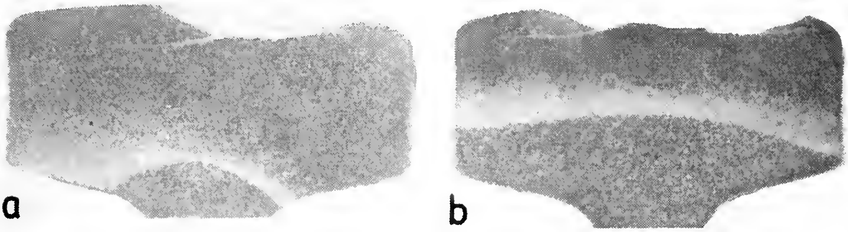


Fig. 3—Two welded engine burns that failed. Etched in ammonium persulfate solution. Note horizontal cracks under weld metal.

Metallographic and Hardness Tests

Fig. 4 shows one specimen as received. Fig. 5 shows a slice of the rail head through the center of a bond etched with ammonium persulfate. It will be noted that there is practically no heat-affected area on the rail head. Fig. 6 is the bond area at about 3× magnification etched in 2 percent nital. It shows a $\frac{1}{32}$-in thick martensite layer on the rail head ajacent to the bond wire. Fig. 7 shows this bond area at 100× magnification etched with 2 percent with Tukon hardness tests converted to Brinell hardness readings.

The top area in Fig. 7 is the bond material with Brinell hardness of 207 to 344 at the weld. The martensite layer on the side of the rail head gave Brinell readings of 525 to 670. The lower area is the original rail steel structure with Brinell hardness of 244 to 286.

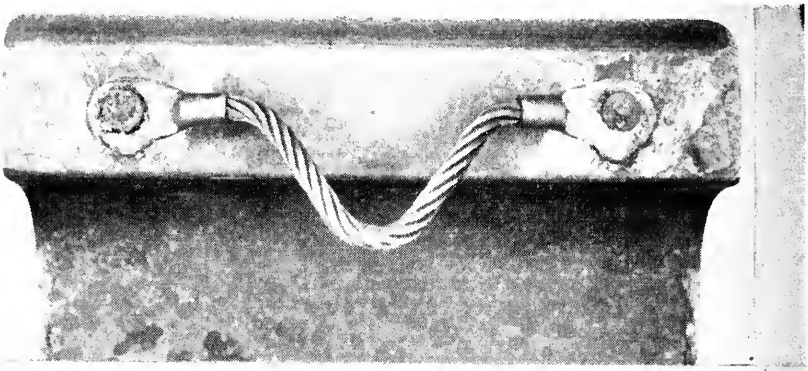
Charpy Tests

Three charpy specimens were cut from three different bonds and tested on un-notched specimens with the martensite layer on the tension side of the specimens. These tests, together with previous tests of torch-welded bonds and thermit-welded bonds as published, are recorded in Table 3.

TABLE 3—CHARPY TESTS—UN-NOTCHED SPECIMENS

Description of Specimen	*Torch-Welded Bonds Ft-Lb*	*Thermit-Welded Bonds Ft-Lb*	*Tigerbraze Welded Bonds Ft-Lb*
No. 1 bond area	7.1	5.7	65.1
No. 2 bond area	3.9	7.1	51.6
No. 3 bond area	-----	-----	55.1
Average	5.5	6.4	57.3
No. 4 rail steel without bonds	139	171	154
No. 5 rail steel without bonds	133	168	145
Average	136	169.5	149

It will be noted that the Tigerbraze specimens gave charpy test results about 10 times as high as the previously tested rail bonds.



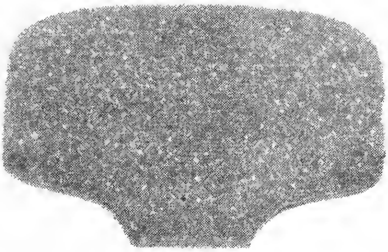
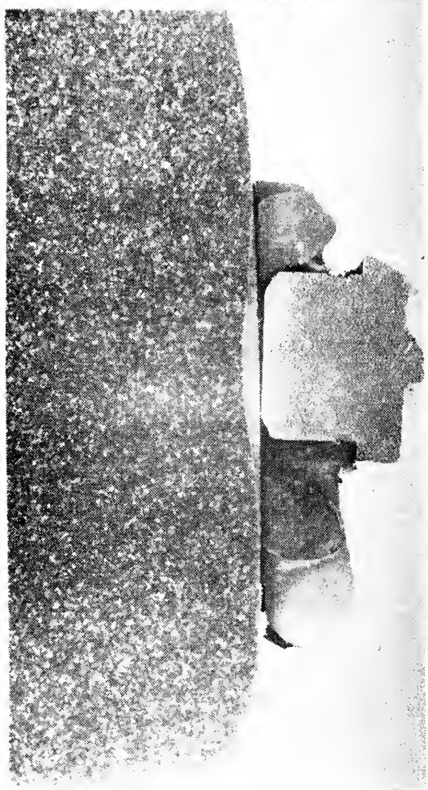


Fig. 4 (Top)—Specimen as received.

Fig. 5 (Above)—Slice through rail bond. Etched with ammonium persulfate.

Fig. 6 (Right)—Macrograph of bond area. Magnification about 3X. Etched 2 percent nital.



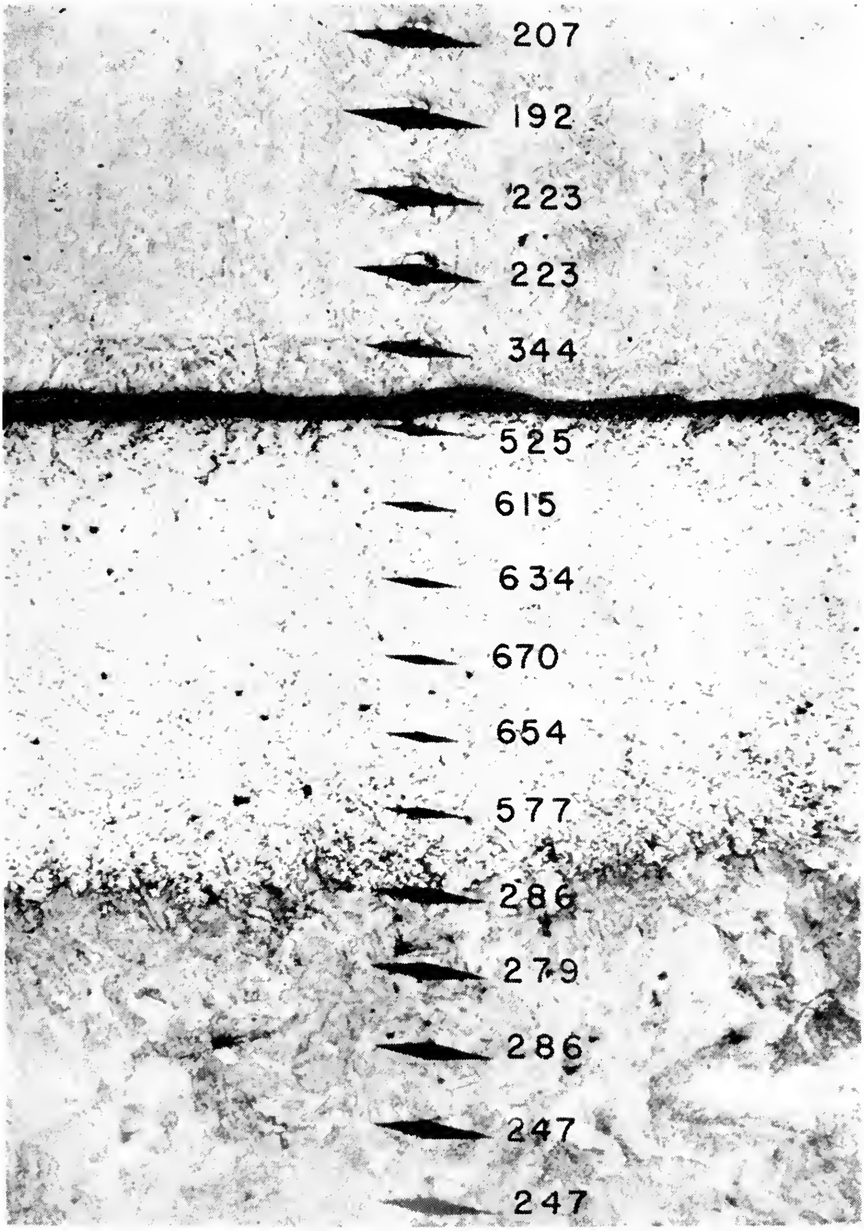


Fig. 7—Photomicrograph of hardness tests in bond area. Magnification 100X. Etch 2 percent nital. Tukon tests converted to Brinell hardness.

Rolling Load Tests

Two specimens for rolling-load tests each had one Tigerbraze bond at the center of the 7-in wheel path. These specimens were rolled in the cradle rolling-load machine with the bond wire on the gage side. A wheel load of 50,000 lb was used, which ordinarily produces a shelling crack in standard rails between 800,000 and 1,200,000 cycles. The results of these rolling-load tests, together with published results of other rail specimens with welded bonds, are shown in Table 4.

TABLE 4—RESULTS OF ROLLING-LOAD TESTS IN CRADLE ROLLING-LOAD MACHINE, 50,000-LB WHEEL LOAD

Specimen	*Cycles for Failure*		
	Torch-Welded Bonds	*Thermit-Welded Bonds*	*Tigerbraze Welded Bonds*
No. 1	1,128,000	1,579,000	3,551,000
No. 2	1,020,000	1,440,000	2,266,700
Average	1,074,000	1,504,500	2,908,800

In previous rolling-load tests of rails with welded bond wires the rail usually failed at the welds. Neither of these two specimens failed at the bonds but developed shelling cracks about 2 in away from the welded bonds at a considerably higher number of cycles than previous tests of welded bonds.

All laboratory tests of the Tigerbraze welded bonds gave results that were superior to previously tested welded rail bonds.

Summary

1. Table 1 gives a summary of the causes of failure of 49 control-cooled rails.

2. Fig. 1 shows a graph of the number of years hot torn steel rails were in service before failure developed.

3. Pictures are included of one compound fissure from an inclusion and two fractures from welded engine burns.

4. Laboratory tests are described of Tigerbraze rail bonds which gave results that were superior to previous tests of other kinds of welded rail bonds.

Report on Assignment 3

Rail Failure Statistics, Covering (a) All Failures; (b) Transverse Fissures; (c) Performance of Control-Cooled Rail

C. J. Code (chairman, subcommittee), F. W. Biltz, B. Bristow, C. B. Bronson, J. K. Gloster, C. B. Harveson, N. W. Kopp, B. R. Meyers, L. T. Nuckols, Embert Osland, G. L. P. Plow, J. G. Roney, I. H. Schram, S. H. Shepley, A. A. Shillander, H. F. Whitmore.

These statistics present the rail failures reported to December 31, 1953, and are submitted as information. They include the failures reported by 62 railroads on all of their main-line railway mileage, which constitutes 90 percent of all of the main-line track in the United States and Canada. This report was prepared by Kurt Kannowski, metallurgical engineer of the AAR Engineering Division research staff, under the direction of G. M. Magee, director of engineering research.

The accompanying tables and diagrams have been prepared to indicate the extent of control of the transverse fissure problem that has been obtained by the use of control-cooled rail and detector car testing; to give data on the quality of each year's rollings for the various mills; and to show the types of failures that are occurring on the various railroads as related to the mill producing the rail.

Transverse Fissure Failures

The number of service transverse fissure failures, as shown by curves "A" and "C" on Fig. 1, again show a decrease. Comparing the data of Table 1, we find for the 62 roads reporting that the service transverse fissure failures decreased from 1320 in 1952 to 1207 in 1953, a reduction of 8 percent. The detector car mileage reported by 59 roads decreased from 227,637.24 track miles tested in 1952 to 212,280.84 track miles tested in 1953. The above reduction in service failures, in spite of somewhat less detector car testing, is indicative of the effect of control-cooled rail and previous testing in reducing service failures. It is of interest to note that most roads decreased their transverse fissure service failures. It will be noted that there was a considerable decrease (18 percent) in the number of detected transverse defects, as is shown by curve "B", Fig. 1. This is partially due to the decreases in detector car test miles (6 percent), but it is also indicative of the benefit of control-cooled rail.

Table 2 has been prepared to give information on the number of detected transverse fissures as contrasted with the number of total detected transverse defects. In this table are included failures on 25 railroads that break all detected defects and verify the type of failure. The data in this table are also shown in Fig. 1, and it will be observed that the detected transverse fissures have declined continuously since 1943. The amount of this decline is more than would be expected from the tonnage of control-cooled rail now in service. Replacement of heats of rail which have developed transverse fissures in service, and the application of control-cooled rail to the heaviest traffic carrying trackage no doubt explains the effectiveness obtained from the tonnage of control-cooled rail now in use.

The Pennsylvania Railroad discontinued breaking rails for verification in 1949 and its results are, therefore, available only for the preceding years.

Mill Performance

Figs. 2 and 3 are presented to show the quality of the rail from the various mills for each year's rolling, as indicated by the failures which develop. Fig. 2, which gives the failures during the first five years of service for all mills collectively, shows that the failure rate has declined steadily and substantially, and that for the 1948 rollings is the lowest so far reported. This speaks well for improvements made in mill quality, rail design, and railway maintenance practices.

The accumulated failures by mills and year of rolling given in Fig. 3 show that for certain mills and certain years the failure rate has been considerably above normal. These instances were explained in last year's report for rollings up to 1952. The 1952 rollings show a high rate at only one mill—Lackawanna—and this was due to 26 "other head" failures reported by the New York Central.

Table 3 shows there was a considerable decrease in the amount of rail laid in 1952. The total tonnage of control-cooled rail laid, as reported from 1935 to date, is 17,717,626 tons, or 94,579.34 track miles. Assuming that most of this rail is still in main track, this would indicate that about 40 percent of main track is now laid with control-cooled rail.

Table 4 and Fig. 4 give the accumulated failure rate of all rollings of control-cooled rail from 1943 to date. The shape of the curve in Fig. 4 is interesting in comparing the failure rate with respect to years of service. The rate is low for the first 5 years, is about 10 times as great for the next 4 years, then drops back to a low rate the tenth year. Whether this is a normal characteristic or due to difference in traffic conditions or mill quality will be determined within the next several years.

Types of Failures

Tables 6 and 7 have been prepared to give information on the types of failures in control-cooled rail. It will be noted from Table 6 that web failures within joint bar limits and detail fractures are the 2 outstanding types of failures, representing 37 percent and 35 percent, respectively, of all failures reported.

It is believed that the new rail sections having the upper web and fillet area strengthened, in conjunction with the new bolt hole spacing and knowledge gained concerning corrosion protection, will effectively control web failures both within and outside joint bar limits. A comparison has been made of the web failures that have been reported in the old rail sections, and those reported in the new sections with the upper fillets strengthened. In the comparison, the old sections were rails laid 1943 to 1947, to include all web failures reported to December 31, 1947.

Old Sections

Year Laid	*Track Miles*	*Web Failures In Joint*	*Web Failures Others*
1943	1760	217	273
1944	2273	169	255
1945	2215	24	19
1946	1848	4	0
1947	2009	1	0
Total	10105	415	547

The comparison on the new sections was made for rail laid 1948–1952, incl., to include all web failures reported to December 31, 1952.

New Sections

Year Laid	*Track Miles*	*Web Failures In Joint*	*Web Failures Others*
1948	1720	11	2
1949	1470	7	1
1950	1462	3	0
1951	1417	0	0
1952	1204	2	2
Total	7273	23	5

Although the service period is too short on the new sections for conclusive results, the above comparison does give good reason to expect that measures already taken will bring web failures well under control.

Because of the rather general use now being made of supersonic devices for detecting bolt hole and rail end fillet cracks, Table 8 has been added this year to give data on service and detected failures of this nature. This table shows the number of failures

(Text continued on page 926)

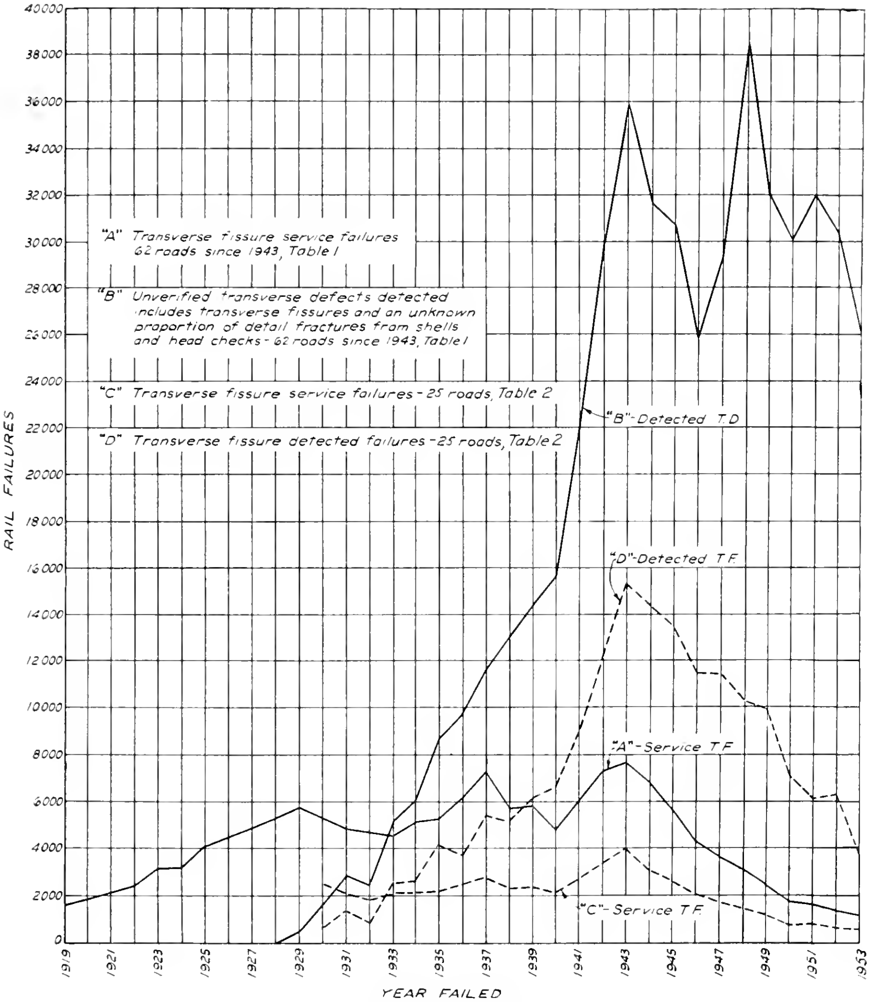


FIG. 1—ANNUAL SERVICE RAIL FAILURES DUE TO TRANSVERSE FISSURES AND TO DETECTED TRANSVERSE DEFECTS AS REPORTED BY ALL RAILROADS.

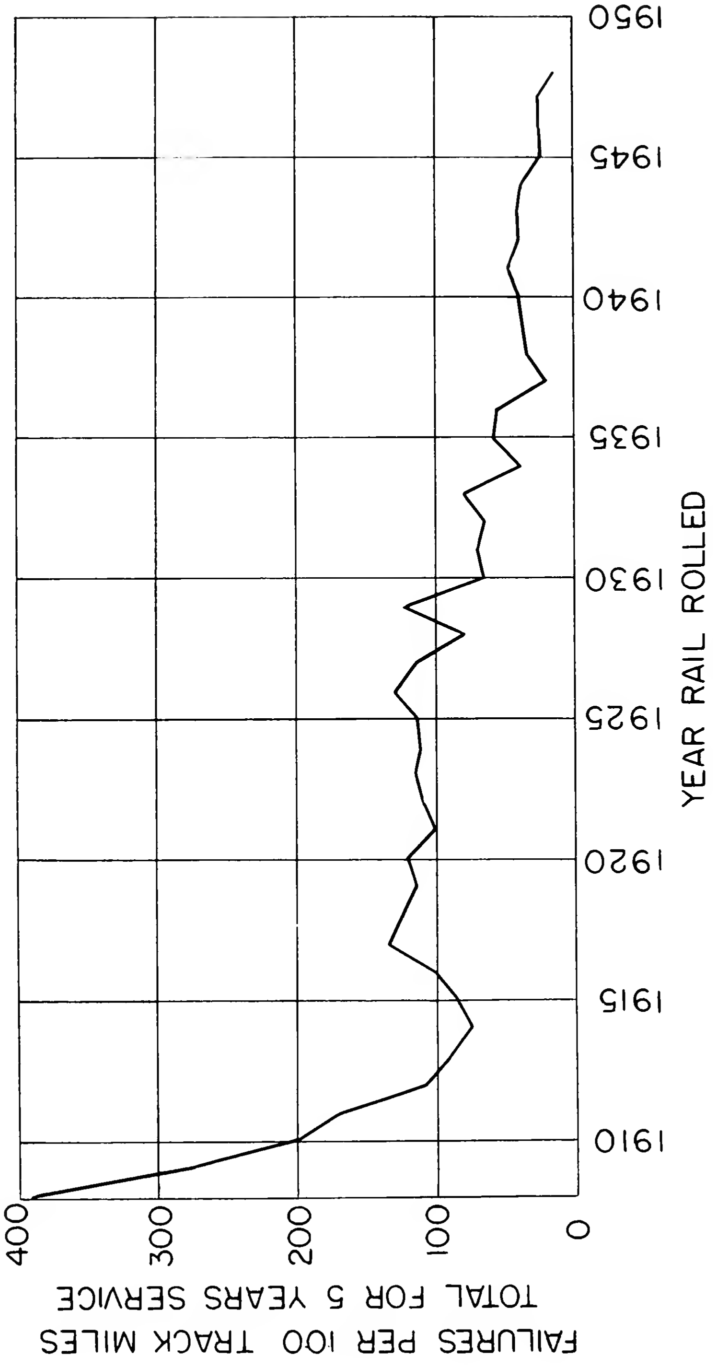


FIG. 2- SERVICE AND DETECTED FAILURES IN UNITED STATES AND CANADA

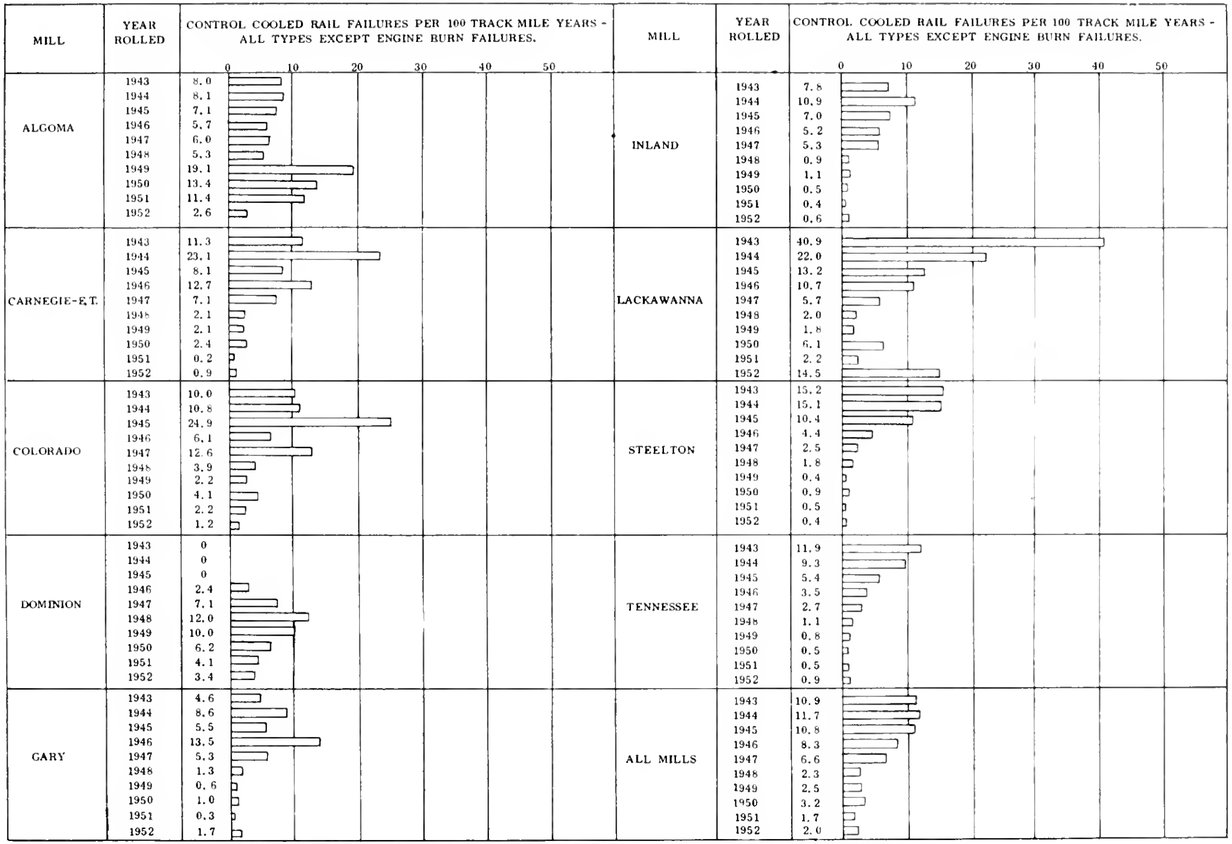


Fig. 3 - Control Cooled Rail Failure Rates to December 31, 1953 by Mills - All Types Except Engine Burn Failures - Service and Detected.

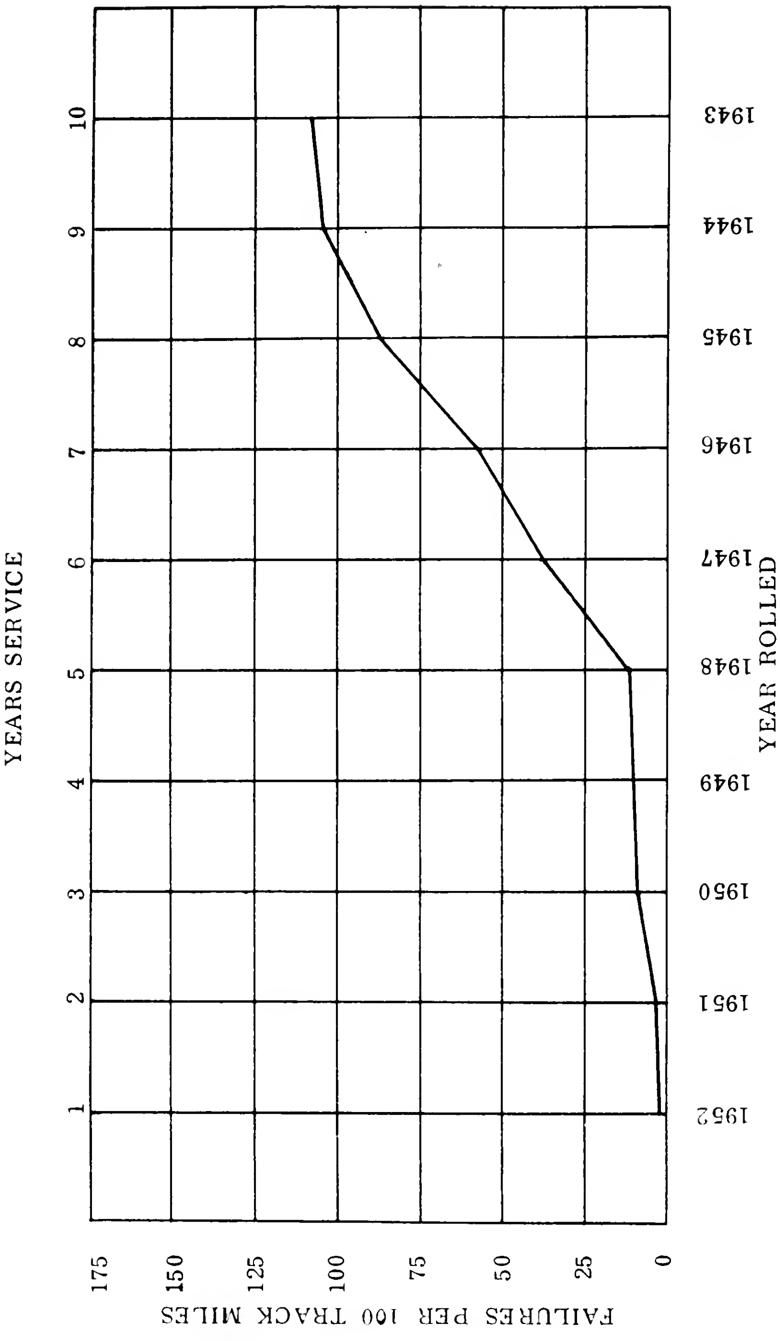


Fig. 4 - Control-Cooled Rail Failures to December 31, 1953 Per 100 Track Miles - All Types Excluding Engine Burn Fractures - Service and Detected.

TABLE 1 - SERVICE FAILURES FROM TRANSVERSE FISSURES AND DETECTED FAILURES FROM TRANSVERSE DEFECTS BY RAILROADS AND BY YEAR FAILED - ALL ROLLINGS BY ALL PROCESSES

	Service Failures											Detected Failures										
Yr. Failed	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	Total	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	Total
AT&SF	307	141	157	112	92	103	39	52	54	18	1075	647	538	580	388	1358	1449	1110	1169	1088	970	9297
ACL	267	50	51	43	14	7	12	9	4	7	464	870	1302	924	1120	1491	919	944	758	741	853	9922
B&O	367	332	205	209	177	100	156	100	91	100	1837	780	844	978	801	713	780	733	745	641	596	7611
B&OCT	2	0	0	12	9	5	1	2	0	2	33	0	0	0	0	2	15	5	2	2	0	26
Ban.&Aroos.	4	3	1	2	0	0	1	0	0	0	11	0	0	49	0	26	16	19	7	11	24	152
B&LE	10	6	9	3	5	3	3	2	2	5	48	0	0	0	0	0	0	0	0	138	36	174
B&M	64	17	11	26	31	16	14	7	24	21	231	276	695	315	212	379	300	375	356	311	292	3511
CP	238	274	214	184	181	131	77	75	47	47	1468	5064	4957	3105	4338	3546	3787	2866	3800	4251	1504	37218
CofGa.	61	58	31	40	31	18	17	24	14	12	306	179	157	184	0	426	275	274	243	301	0	2039
C of NJ	71	48	45	61	65	37	48	14	14	11	414	0	0	3	0	0	0	0	0	56	15	74
C&O-Ches	71	57	68	88	64	37	22	29	43	21	500	393	458	465	559	1108	845	512	637	678	680	6335
C&O-PM	4	1	1	0	0	0	0	0	0	0	6	87	27	23	0	11	5	2	6	6	3	170
C&EI	51	62	57	42	33	41	17	15	21	18	357	352	304	338	316	317	320	265	212	97	150	2671
C&NW	160	135	137	168	149	118	84	85	74	72	1182	1578	1641	1176	1461	976	1159	816	1216	817	836	11676
CB&Q	287	244	141	152	144	65	59	59	28	23	1202	1245	1342	1408	885	954	975	465	679	687	463	9103
CI&L	12	16	8	6	7	0	4	4	5	2	64	19	21	57	2	114	77	151	80	58	58	637
CMStP&P	136	132	79	87	89	61	48	42	45	44	763	1062	1083	1069	1173	914	1080	675	763	733	982	9534
CRI&P	183	168	123	127	83	47	48	56	46	49	930	645	643	527	552	596	620	445	369	537	322	5256
C&S	26	21	3	10	3	5	2	0	4	-	74	28	47	82	17	189	72	164	55	182	-	836
D&H	67	31	14	19	12	12	6	10	10	5	186	192	196	114	111	314	508	306	430	367	327	2865
DL&W	27	29	36	22	17	8	7	3	5	-	154	333	300	303	375	319	186	270	225	257	-	2568
D&RGW	203	212	159	22	31	15	16	14	-	-	672	114	254	190	14	695	373	741	645	-	-	3026
Erie	177	99	98	87	58	43	24	19	20	19	644	971	549	666	619	776	570	543	475	459	435	6063
FEC	152	92	67	86	55	39	27	1	7	0	526	367	119	164	279	182	243	26	13	30	94	1517
GTW	43	43	13	20	27	19	11	9	7	16	208	112	112	83	89	110	123	118	85	71	96	999
GN	243	247	266	175	175	+102	85	94	63	47	1497	430	535	516	430	1531	936	1167	1069	1525	932	9071
GM&O	29	54	-	26	35	-	-	-	-	-	144	306	60	-	265	274	-	-	-	-	-	905
IC(Sys)	311	197	64	65	59	69	53	55	28	33	934	1925	1907	1314	1418	1650	1284	1296	1226	1279	1088	14387
KCS	14	21	4	0	10	8	4	6	6	0	73	178	66	94	0	94	73	100	93	94	89	881
L&HR	8	0	0	4	0	0	0	1	1	0	14	24	13	12	6	0	0	0	11	8	8	82
L&NE	5	2	7	2	5	0	0	0	1	0	22	4	15	16	13	36	4	12	12	12	0	124
LV	33	49	22	22	14	6	14	12	20	8	200	189	156	67	127	55	126	87	163	105	108	1183

TABLE 1 (Continued)

	Service Failures											Detected Failures										
Yr. Failed	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	Total	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	Total
LI	-	-	-	-	-	0	0	0	0	0	0	-	-	-	-	-	25	26	18	25	15	109
L&N	160	159	116	133	115	60	48	63	40	40	934	747	684	648	653	933	864	743	843	926	711	7752
Me.Cen.	12	15	14	0	0	7	6	2	3	2	61	21	63	50	0	0	74	130	89	55	46	528
MStP&SSM	13	49	23	30	21	17	11	11	6	0	181	39	24	96	90	95	73	104	116	138	81	856
MKT	92	57	28	31	30	24	16	19	13	14	324	515	214	141	118	576	532	359	290	162	270	3177
MP RR	-	-	-	-	-	-	*47	44	43	34	168	-	-	-	-	-	-	1109	835	770	639	3353
MP Lines	25	24	31	42	4	24	10	28	8	8	204	728	399	462	507	553	518	370	473	497	342	4849
NC&StL	58	43	32	19	9	9	7	6	5	4	192	172	184	68	84	104	59	45	43	43	11	813
NYC(Sys)#	406	344	225	202	173	165	154	177	130	155	2131	559	1119	750	724	1484	1508	1306	1344	1284	1151	11229
NYC&StL	86	47	29	45	37	21	19	16	13	10	323	318	199	215	172	128	118	106	84	77	60	1477
NYC Trans.	3	3	6	2	15	-	-	-	-	-	29	0	0	0	0	0	-	-	-	-	-	0
NYNH&H	21	14	3	5	4	2	3	1	0	2	55	136	74	86	68	172	79	116	77	48	73	929
NYO&W	62	6	1	24	24	12	21	25	10	8	193	53	0	56	2	0	0	11	20	86	110	338
N&W	3	1	5	3	2	3	3	1	3	2	26	40	40	58	17	129	84	130	124	157	113	892
NP	310	288	289	188	129	90	73	11	1	0	1379	440	471	702	475	431	473	347	377	372	417	4505
PRR##	365	415	290	259	255	430	92	103	85	122	2416	1026	909	646	644	1865	1166	1876	1844	1322	1792	13090
P&LE	4	0	3	0	1	0	0	1	0	0	9	4	6	1	5	36	22	29	12	20	26	161
Reading	173	70	49	47	0	0	0	0	0	0	339	367	735	287	321	1236	404	241	451	205	396	4643
RF&P	31	27	20	12	10	6	1	0	0	1	108	228	207	176	106	514	195	172	128	64	55	1845
Rutland	3	1	2	1	0	0	0	4	0	2	13	0	0	0	9	0	0	0	28	0	0	37
StL-SF	111	142	102	101	74	52	17	16	0	3	618	573	655	415	532	664	639	515	377	410	398	5178
SAL	49	23	24	21	11	18	22	7	14	7	196	197	159	299	440	412	299	454	324	318	344	3246
SP(PacLine)	445	267	209	179	162	98	68	75	76	69	1648	1536	1377	1362	909	1243	1012	952	960	970	1005	11326
Sou(Sys)	278	277	246	188	171	98	98	106	70	63	1595	2360	1955	1835	1998	2643	2009	1927	1682	1490	1622	19521
T&NO	239	186	123	66	112	99	90	88	79	55	1137	795	924	837	739	951	1006	958	788	749	606	8353
T&P	128	124	72	71	46	22	16	8	7	5	499	869	582	524	0	393	173	152	114	90	70	2967
UP(Sys)	226	241	176	172	55	19	23	13	15	13	953	1587	1356	1148	4957	4149	3613	3429	4142	4157	4632	33170
Virginian	11	13	10	4	6	1	0	0	1	0	46	114	0	0	0+	152	24	60	73	45	39	507
W.Md.	26	27	14	33	25	3	16	15	14	8	181	184	133	144	224	418	302	138	133	156	153	1985
W&LE	3	3	5	1	0	3	7	-	-	-	22	0	3	3	0	8	5	11	-	-	-	30
ALL ROADS	6976	5707	4238	3801	3166	2398	1767	1639	1320	1207	32219	31978	30813	25831	29364	38445	32396	30303	31333	30178	26138	306779

*Includes all transverse defects
-No report received

#Includes IHB failures
##Including LI RR and PRSL 1940 to 1948 inclusive
+Includes engine burn fractures

TABLE 2 - SERVICE AND VERIFIED DETECTED TRANSVERSE FISSURE FAILURES BY RAILROAD AND BY YEAR FAILED REPORTED BY ROADS WHICH BREAK THEIR DETECTED RAILS. ALL ROLLINGS BY ALL PROCESSES.

	Service Failures											Detected Failures										
Yr. Failed	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	Total	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	Total
AT&SF	307	141	157	112	92	103	39	52	54	18	1075	647	538	580	388	298	488	359	362	308	213	4181
Ban&Aroos	4	3	1	2	0	0	1	0	0	0	11	0	0	49	0	26	11	19	7	11	24	147
CP	238	274	214	184	181	131	77	75	47	47	1468	5064	4957	3105	4338	3545	3787	2866	1900	2125	0	31687
C&EI	51	62	57	42	33	41	17	15	21	18	357	352	304	338	316	312	320	245	187	97	0	2471
CB&Q	287	244	141	152	144	65	59	59	28	23	1202	1245	1342	1408	885	887	884	426	528	544	372	8521
CMStP&P	136	132	79	87	89	61	48	42	45	44	763	1062	1083	1069	1173	734	901	557	567	495	546	8187
C&S	26	21	3	10	3	5	2	0	4	-	74	28	47	82	17	56	37	53	45	71	-	436
Erie	177	99	98	87	58	43	24	19	20	19	644	971	549	666	619	595	469	463	350	276	326	5284
GTW	43	43	13	20	27	19	11	9	7	16	208	112	112	83	89	106	123	118	85	71	96	995
GN	243	247	266	175	175	102	85	94	63	47	1497	430	535	516	430	631	599	519	546	662	362	5230
LI*	-	-	-	-	-	0	0	0	0	0	0	-	-	-	-	-	25	26	18	25	15	109
L&N	160	159	116	133	115	60	48	63	40	40	934	747	684	648	653	662	554	483	524	300	545	5800
MKT	92	57	28	31	30	24	16	19	13	14	324	515	214	141	118	280	264	176	265	157	266	2396
NC&StL	58	43	32	19	9	9	7	6	5	4	192	172	184	68	84	87	58	39	34	38	10	774
NYC(Sys)	406	344	225	202	173	165	154	177	130	155	2131	559	1119	750	724	690	693	673	648	722	759	7337
NYC&StL	86	47	29	45	37	21	19	16	13	10	323	318	199	215	172	128	116	0	0	77	60	1285
NYNH&H	21	14	3	5	4	2	3	1	0	2	55	136	74	86	68	132	60	107	64	43	57	827
N&W	3	1	5	3	2	3	3	1	3	2	26	40	40	58	17	29	28	32	16	36	19	315
NP	310	288	289	188	129	90	73	11	1	0	1379	440	471	702	475	355	441	41	22	68	58	3073
PRR	365	415	290	259	255	430	92	103	85	122	2416	1026	909	646	644	404	16	0	0	0	0	3645
P&LE	4	0	3	0	1	0	0	1	0	0	9	4	6	1	5	0	0	3	3	7	9	38
RF&P	31	27	20	12	10	6	1	0	0	1	108	228	207	176	106	147	49	22	12	0	1	948
Rutland	3	1	2	1	0	0	0	4	0	2	13	0	0	0	9	0	0	0	14	0	0	23
Va	11	13	10	4	6	1	0	0	1	0	46	114	0	0	0	1	0	0	0	0	3	118
W. Md.	26	27	14	33	25	3	16	15	14	8	181	184	133	144	224	210	141	66	77	81	25	1285
Total	3088	2702	2095	1806	1598	1384	795	782	594	592	15436	14394	13707	11531	11554	10315	10064	7293	6274	6214	3766	95112

*Included in PRR prior to 1949
-No report received.

TABLE 3 - TONS OF RAILS AND TRACK MILES OF EACH YEAR'S ROLLINGS 1943 - 1952 INCL., REPORTED BY 64 RAILROADS.

Year Rolled	OH CONTROL COOLED ONLY		BRUNORIZED AND OTHER PROCESS		TOTAL	
	TONS	TRACK MILES	TONS	TRACK MILES	TONS	TRACK MILES
1943	1,252,246	6,816.40	11,443	77.24	1,263,689	6,893.64
1944	1,517,408	8,183.03	7,845	54.12	1,525,253	8,237.15
1945	1,487,946	7,951.68	0	0	1,487,946	7,951.68
1946	1,220,396	6,469.42	0	0	1,220,396	6,469.42
1947	1,393,935	7,236.28	0	0	1,393,935	7,236.28
1948	1,279,778	6,601.31	0	0	1,279,778	6,601.31
1949	1,140,253	5,966.41	0	0	1,140,253	5,966.41
1950	1,191,853	6,335.78	0	0	1,191,853	6,335.78
1951	1,117,510	5,908.58	0	0	1,117,510	5,908.58
1952	897,278	4,796.63	0	0	897,278	4,796.63
TOTAL	12,498,603	66,265.52	19,288	131.36	12,517,891	66,396.88

TABLE 4 - SERVICE AND DETECTED FAILURES OF ALL TYPES EXCEPT ENGINE BURN FAILURES ACCUMULATED FROM DATE ROLLED TO DECEMBER 31, 1953 PER 100 AVERAGE TRACK MILES, CONTROL COOLED RAIL ONLY, IN ALL ROLLINGS, FROM ALL MILLS.

Year Rolled	YEARS OF SERVICE									
	1	2	3	4	5	6	7	8	9	10
1943	3.4	8.4	16.5	23.9	34.9	48.7	66.1	90.0	103.7	108.8
1944	3.6	7.2	13.8	19.4	33.3	46.1	61.2	84.6	105.5	
1945	1.4	4.1	8.6	15.7	28.8	43.9	65.8	87.4		
1946	1.2	2.9	6.6	12.9	25.1	41.0	57.8			
1947	0.9	3.1	6.5	13.6	25.5	39.6				
1948	0.7	1.6	3.6	7.5	11.5					
1949	1.7	4.1	7.2	10.0						
1950	3.1	6.0	9.6							
1951	2.0	3.4								
1952	2.0									

TABLE 5 - TRACK MILES AND 1953 FAILURES, ALL TYPES, IN ROLLINGS 1943 TO 1952, INCL., OPEN-HEARTH CONTROL-COOLED RAIL ONLY

	TRACK MILES BY MILL										1953 FAILURES ONLY	
ROAD	ALG	CARN	COLO	DOM	GARY	INLD	LACKA	STLTN	TENN	TOTAL	EBFS EXCL	EBFS ONLY
AT&SF			2935		1142	170				4247	135	0
ACL		101						720	1177	1998	283	0
B&O		1053			344	10	212	684		2303	150	89
B&OCT					19	27				46	0	0
Ban & Aroos		3						167		170	0	0
B&LE		110								110	2	1
Bos & Alb					4		178			182	2	0
B&M		105					137	103		345	29	1
CP	4841			643			160			5644	321	0
C of Ga									414	414	12	0
C&O-Ches E Regn		80			1031	571	66	139		1887	113	27
C&O-PM	76				234	107	63			480	1	0
C&EI					204	37				241	18	7
C&NW					842	177	152			1171	45	1
CB&Q			1216		955	172				2343	51	0
CI&L					117	36				153	0	0
CMStP&P					1512	419				1931	3	0
CRI&P			244		1117	333				1694	16	0
CCC&StL-P&E					738	59	37			834	176	5
C&S			182							182	2	4
D&H								318		318	47	0
D&RGW			514							514	42	0
Erie		700			279	26	132			1137	11	4
FEC		29						90	488	607	5	2
GTW					359	93	71			523	18	0
GN			270		798	249	256			1573	83	0
IC					1520	603			283	2406	61	3
IHB						17				17	0	0
JCL								176		176	0	0
KCS					357	49				406	4	0
L&HR								30		30	0	0
L&NE								52		52	0	0
LV							333			333	1	0
L. I.								121		121	0	0
L&N					197				1620	1817	131	9
Me. Cen							103			103	1	0
MStP&SSM					244	169	102			515	10	1
MKT			104		467	103				674	10	1
MP RR			1027		519	164				1710	18	0
MP Lines			454						210	664	4	4
NC&StL					4				549	553	29	0
NY&LB								22		22	0	0
NYC-E					62		1305			1367	590	5

TABLE 5 - CONTINUED

ROAD	TRACK MILES BY MILL										1953 FAILURES ONLY	
	ALG	CARN	COLO	DOM	GARY	INL'D	LACKA	STLTN	TENN	TOTAL	EBFS EXCL	EBFS ONLY
NYC-W					620	37	59			716	177	2
NYC&StL		184			505	110	231			1030	186	1
NYNH&H		181						321		502	38	7
NYO&W							9			9	2	0
N&W		984						384		1368	141	14
NP			508		539	89	268			1404	55	3
PRR		1213			452	97		1272		3034	747	93
P&LE		166								166	121	2
Reading								540		540	3	0
RF&P								180		180	257	0
Rutland							4			4	0	0
StL-SF					10	51			800	861	28	0
SAL		3						946	548	1497	17	0
SP			3635							3635	460	100
Southern					107			830	1168	2105	67	3
T&NO			693						101	794	18	1
T&P			568						99	667	0	0
UP			2377		849	130				3356	2231	2
Va		86						139		225	18	0
WMd		147						216		363	57	0
TOTAL	4917	5145	14727	643	16147	4105	3878	7450	7457	64469	7047	392

TABLE 6 - ACCUMULATED FAILURES AND FAILURES PER 100 TRACK MILES, IN ROLLINGS 1943 TO 1952, INCLUSIVE FROM DATE ROLLED TO DECEMBER 31, 1953, SERVICE AND DETECTED, BY MILL AND TYPE OF FAILURE.

OH CONTROL COOLED RAIL ONLY

MILL	ACCUMULATED FAILURES TO DEC. 31, 1953 (EXCL. EBFs)									ALL TYPES	TRACK MILES	TRACK MILE YEARS	FAILURES PER 100 TRACK MI. YEARS
	TF VER U of I	CF & DF	VSH	HSH	OTHER HEAD	BROKEN	WEB IN JT.	WEB OTHER	BASE				
ALGOMA	4	9	276	12	269	121	452	49	1116	2308	4917	28280	8.16
CARNEGIE (ET)	5	484	55	83	112	86	1621	397	9	2852	5145	27903	10.22
COLORADO	0	6243	383	588	569	89	722	628	18	9240	14727	87384	10.57
DOMINION	0	0	14	2	8	4	46	7	11	92	643	1677	5.49
GARY	3	1252	129	84	361	269	3021	264	63	5446	16147	92513	5.89
INLAND	9	392	48	18	38	126	463	90	24	1208	4105	21329	5.71
LACKAWANNA	16	172	77	27	163	75	2568	51	112	3261	3878	22195	14.69
STEELTON	19	1283	40	48	69	123	1219	107	7	2915	7450	40566	7.19
TENNESSEE	1	394	141	345	226	192	782	130	50	2261	7457	41151	5.49
ALL MILLS	57	10229	1163	1207	1815	1085	10894	1723	1410	29583	64469	362998	8.14
FAILURES 100 TR. MI. YEARS	.01	2.82	.32	.33	.50	.30	3.00	.47	.39	8.15			

TABLE 7 - ACCUMULATED FAILURES OF ALL TYPES OF OH CONTROL COOLED RAIL ONLY, IN ROLLINGS 1943-1952, INCL., ACCUMULATED TO DECEMBER 31, 1953, SEGREGATED BY ROADS AND MILLS, FROM TABLE 6, EXCLUSIVE OF ENGINE BURN FRACTURES SHOWN SEPARATELY FOR 1952 ONLY AND TOTAL ACCUMULATED 1944-1953, INCL.

ROADS	TF Ver UofI	CF & DF	VSH	HSH	Other Head	Broken	Web In Jt	Web Other	Base	FAILURES TOTALS EBFs Excl. Accum. Total	EBFs Excl. 1953	EBFs Only 1944 1953	EBFs Only 1953
ALGOMA													
CP	4	9	274	12	269	121	452	49	1115	2305	272	0	0
C&O-PM	0	0	2	0	0	0	0	0	1	3	0	0	0
TOTAL	4	9	276	12	269	121	452	49	1116	2308	272	0	0
CARNEGIE													
ACL	0	0	0	0	0	0	17	1	0	18	18	0	0
Ban&Aroos	0	0	0	0	0	0	0	0	0	0	0	0	0
B&O	0	66	29	16	32	12	163	92	1	411	69	109	36
B&LE	0	1	0	2	0	0	0	0	0	3	2	1	1
B&M	4	4	1	0	15	2	2	24	1	53	9	0	0
C&O-Ches.	0	2	0	0	0	0	2	0	0	4	0	2	0
Erie	0	20	1	2	1	2	0	5	1	32	8	14	3
FEC	0	0	0	0	0	0	0	0	0	0	0	0	0
NYC&StL	0	4	4	11	20	20	170	12	0	241	74	3	0
NYNH&H	0	14	5	14	2	4	33	5	0	77	31	7	1
N&W	0	299	5	19	26	0	72	35	5	461	105	24	11
PRR	0	50	6	16	16	12	801	204	1	1106	118	340	66
P&LE	0	9	2	1	0	0	361	5	0	378	121	17	2
SAL	0	0	0	0	0	0	0	0	0	0	0	0	0
Va	0	13	0	2	0	15	0	10	0	40	2	0	0
WMd	1	2	2	0	0	19	0	4	0	28	27	0	0
TOTAL	5	484	55	83	112	86	1621	397	9	2852	584	517	120
COLORADO													
AT&SF	0	145	38	79	17	11	136	8	2	436	123	0	0
CB&Q	0	1	8	12	13	5	176	23	1	239	16	2	0
CRI&P	0	0	6	0	6	24	3	0	2	41	2	0	0
C&S	0	0	0	0	2	0	0	0	0	2	2	4	4
D&RGW	0	193	12	20	6	1	15	1	0	248	42	0	0
GN	0	0	1	0	3	0	1	0	0	5	2	0	0
MKT	0	0	2	3	1	0	0	2	0	8	2	0	0
MP RR	0	[illegible]	31	7	28	4	57	21	0	155	10	0	0
MP Lines	0	0	8	3	4	7	13	2	3	40	4	10	4
NP	0	0	0	3	27	3	6	7	0	46	19	6	1
SP	0	156	199	347	231	33	286	421	10	1683	460	185	100
T&NO	0	6	6	16	5	0	1	50	0	84	14	1	1
T&P	0	0	3	0	1	1	10	0	0	15	0	0	0
UP	0	5735	69	98	225	0	18	93	0	6238	1865	1	0
TOTAL	0	6243	383	588	569	89	722	628	18	9240	2561	209	110

TABLE 7 - CONTINUED

ROADS	TF Ver UofI	CF & DF	VSH	HSH	Other Head	Broken	Web In Jt	Web Other	Base	FAILURES TOTALS EBFs Excl. Accum Total	EBFs Excl. 1953	EBFs Only 1944 1953	EBFs Only 1953
DOMINION													
CP	0	0	14	2	8	4	46	7	11	92	37	0	0
TOTAL	0	0	14	2	8	4	46	7	11	92	37	0	0
GARY													
AT&SF	0	0	4	6	5	5	24	0	0	44	12	0	0
B&O	0	0	7	1	4	1	49	7	3	72	11	54	20
B&OCT	0	0	0	1	0	0	1	0	0	2	0	0	0
Bos&Alb	0	0	0	0	0	0	2	0	0	2	0	0	0
C&O-Ches	2	208	5	3	8	8	53	24	0	311	45	115	21
C&O-PM	0	0	5	1	2	0	0	0	0	8	1	0	0
C&EI	0	0	4	4	13	5	28	4	0	58	15	4	3
C&NW	0	9	5	3	30	46	346	5	4	448	25	2	1
CB&Q	0	0	12	9	5	0	31	8	0	65	14	1	0
CI&L	0	0	1	0	0	1	0	0	0	2	0	0	0
CMStP&P	0	1	0	0	1	41	1	3	2	49	2	0	0
CRI&P	0	0	4	7	7	56	6	3	11	94	12	0	0
CCC&StL	0	5	9	8	32	2	535	57	1	649	176	11	5
Erie	0	18	0	0	0	1	4	2	1	26	2	1	1
GTW	1	1	9	0	4	46	16	0	19	96	15	0	0
GN	0	260	6	3	132	18	37	10	1	467	59	2	0
IC	0	24	18	12	4	6	68	9	3	144	28	11	2
KCS	0	12	2	3	1	2	0	1	1	22	3	6	0
L&N	0	8	1	1	1	0	4	3	0	18	1	0	0
MStP&SSM	0	0	5	0	1	7	0	1	6	20	4	0	0
MKT	0	0	6	3	13	0	11	5	0	38	4	1	1
MP RR	0	0	2	2	2	4	158	5	2	175	7	0	0
NC&StL	0	0	1	0	2	0	1	1	0	5	0	0	0
NYC-E	0	31	1	2	0	0	21	0	0	55	13	1	0
NYC-W	0	32	4	0	14	1	600	0	2	653	175	19	2
NYC&StL	0	8	3	5	22	4	318	29	1	390	83	2	0
NP	0	0	7	2	8	7	15	8	2	49	19	1	1
PRR	0	6	2	1	1	6	685	38	1	740	329	11	6
StL-SF	0	0	0	0	2	0	0	1	0	3	0	0	0
Southern	0	1	0	0	2	2	1	2	1	9	0	1	0
UP	0	628	6	7	45	0	6	38	2	732	281	2	2
TOTAL	3	1252	129	84	361	269	3021	264	63	5446	1336	245	65

TABLE 7 - CONTINUED

ROADS	TF Ver UofI	CF & DF	VSH	HSH	Other Head	Broken	Web		Base	FAILURES TOTALS			
										EBFs Excl.		EBFs Only	
							In Jt.	Other		Accum. Total	1953	1944 1953	1953
INLAND													
AT&SF	0	1	0	0	0	0	0	0	0	1	0	0	0
B&O	0	0	1	0	0	0	0	0	0	1	0	0	0
B&OCT	0	0	0	0	0	0	0	0	0	0	0	0	0
C&O-Ches	3	201	6	1	3	18	30	8	1	271	35	22	6
C&O-PM	0	2	2	1	0	0	0	0	1	6	0	0	0
C&EI	0	0	3	0	2	0	3	0	0	8	3	7	4
C&NW	0	8	8	4	5	17	101	2	5	150	16	0	0
CB&Q	4	2	1	1	2	2	20	1	0	33	21	0	0
CI&L	0	0	0	0	0	0	0	0	0	0	0	0	0
CMStP&P	1	0	3	1	1	39	1	2	2	50	1	0	0
CRI&P	0	0	0	1	3	15	2	0	2	23	2	0	0
CCC&StL	0	0	0	0	0	0	0	0	0	0	0	0	0
Erie	0	0	0	0	0	1	0	1	0	2	0	0	0
GTW	0	0	1	0	3	16	3	0	5	28	2	0	0
GN	0	0	3	1	8	0	2	0	1	15	8	0	0
IC	0	20	9	0	0	3	49	4	2	87	28	2	1
IHB	0	0	0	0	0	0	1	1	0	2	0	0	0
KCS	0	1	0	0	0	0	0	3	0	4	1	0	0
MStP&SSM	0	0	1	0	0	9	0	3	4	17	1	0	0
MKT	0	1	3	2	4	0	4	3	0	17	4	1	0
MP RR	0	1	4	1	0	0	3	1	0	10	1	0	0
NYC-W	0	0	0	0	0	0	1	0	0	1	0	0	0
NYC&StL	0	0	2	0	2	2	90	8	1	105	20	0	0
NP	1	0	0	0	3	0	1	0	0	5	5	1	1
PRR	0	1	0	3	0	3	152	52	0	211	13	6	0
StL-SF	0	0	0	1	0	0	0	0	0	1	1	0	0
UP	0	154	1	1	2	1	0	1	0	160	85	0	0
TOTAL	9	392	48	18	38	126	463	90	24	1208	247	39	12
LACKAWANNA													
B&O	0	2	21	0	1	2	46	17	0	89	23	33	7
Bos&Alb	0	1	2	0	0	0	15	0	3	21	2	0	0
B&M	9	16	4	0	21	4	2	0	2	58	15	1	1
CP	0	0	10	3	23	0	3	2	37	78	12	0	0
C&O-Ches	1	14	0	0	1	0	0	2	0	18	9	0	0
C&O-PM	0	0	0	0	0	0	0	0	0	0	0	0	0
C&NW	0	0	0	2	5	3	3	0	8	21	4	0	0
CCC&StL	0	0	1	0	6	1	21	10	0	39	0	0	0
Erie	0	17	0	0	0	2	0	2	1	22	1	0	0
GTW	0	0	27	0	2	5	1	0	3	38	1	0	0
GN	0	10	2	1	53	0	13	2	6	87	14	0	0
LV	0	4	0	0	0	1	0	0	13	18	1	0	0
Me. Cen.	0	0	1	0	4	0	30	4	0	39	1	0	0
MstP&SSM	0	0	1	0	0	18	0	1	6	26	5	2	1
NYC-E	3	103	8	18	38	12	2378	2	13	2575	577	17	5
NYC-W	0	1	0	2	1	0	4	0	1	9	2	1	0
NYC&StL	3	3	0	1	6	6	44	7	1	71	9	1	1
NYO&W	0	0	0	0	0	0	2	0	0	2	2	0	0
NP	0	1	0	0	2	21	6	2	18	50	12	0	0
Rutland	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	16	172	77	27	163	75	2568	51	112	3261	690	55	15

TABLE 7 - CONTINUED

ROADS	TF Ver UofI	CF & DF	VSH	HSH	Other Head	Broken	Web In Jt.	Web Other	Base	FAILURES TOTALS EBFs Excl. Accum. Total	FAILURES TOTALS EBFs Excl. 1953	FAILURES TOTALS EBFs Only 1944 1953	FAILURES TOTALS EBFs Only 1953
STEELTON													
ACL	0	0	0	0	0	0	35	3	1	39	37	0	0
B&O	5	78	12	7	4	3	53	37	2	201	47	92	26
Ban&Aroos	0	0	1	0	0	1	0	0	0	2	0	0	0
B&M	1	9	4	2	12	4	2	0	1	35	5	0	0
C&O-Ches	2	147	4	2	3	0	6	6	0	170	24	4	0
D&H	0	180	2	10	6	7	6	14	0	225	47	5	0
FEC	0	1	0	1	0	0	0	0	0	2	0	1	0
JCL	0	0	0	0	0	0	1	1	0	2	0	0	0
L&NE	0	0	0	0	0	0	2	11	0	13	0	0	0
L&HR	0	0	0	0	0	0	0	0	0	0	0	0	0
LI	0	0	0	0	0	0	0	0	0	0	0	0	0
NY&LB	0	0	0	0	0	0	0	0	0	0	0	0	0
NYNH&H	2	16	1	3	0	1	7	0	0	30	7	11	6
N&W	1	128	0	3	11	0	28	9	1	181	36	5	3
PRR	0	519	4	15	27	38	812	1	0	1416	287	152	21
Reading	0	1	0	0	0	2	1	5	0	9	3	1	0
RF&P	1	130	2	1	3	0	252	0	0	389	257	3	0
SAL	0	0	6	0	0	9	3	3	0	21	6	0	0
Southern	1	17	0	0	2	21	6	0	0	47	15	18	0
Va	2	51	2	2	0	21	5	12	2	97	16	0	0
WMd	4	6	2	2	1	16	0	5	0	36	30	0	0
TOTAL	19	1283	40	48	69	123	1219	107	7	2915	817	292	56
TENNESSEE													
ACL	0	2	7	12	2	2	249	14	3	291	228	16	0
C of Ga	1	8	6	17	11	6	63	4	10	126	12	14	0
FEC	0	13	0	5	0	1	6	0	0	25	5	13	2
IC	0	14	15	3	0	4	35	3	1	75	5	0	0
L&N	0	304	57	205	21	31	284	43	13	958	130	25	9
MP Lines	0	0	0	0	0	0	1	0	0	1	0	0	0
NYC&StL	0	27	36	74	101	15	101	33	7	394	29	0	0
StL-SF	0	23	11	13	19	17	4	17	0	104	27	0	0
SAL	0	0	5	7	0	7	7	2	2	30	11	0	0
Southern	0	2	4	8	70	107	24	11	7	233	52	20	3
T&NO	0	0	0	0	1	0	0	3	6	10	4	0	0
T&P	0	1	0	1	1	2	8	0	1	14	0	0	0
TOTAL	1	394	141	345	226	192	782	130	50	2261	503	88	14
ALL MILLS	57	10229	1163	1207	1815	1085	10894	1723	1410	29583	7047	1445	392

TABLE 8
RAIL FAILURES IN THE WEB WITHIN THE JOINT BAR LIMITS FOUND IN 1953
ON RAIL OF 100 LB. AND ALL HEAVIER SECTIONS

Railroad	Rail Rolled Previous to 1937				Rail Rolled in 1937 and after			
	Detected Failures		Service Failures		Detected Failures		Service Failures	
	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other
AT&SF	98	102	37	33	95	159	73	31
ACL	0	9	15	17	12	523	1	4
Ban & Aroos	9	0	7	4	0	0	0	0
B&LE	0	0	0	0	0	0	0	0
B&M	86	63	11	3	3	0	1	5
CP	0	0	47	2	1	0	132	6
C of Ga	0	0	0	0	3	1	7	5
C of NJ	19	6	5	2	16	0	4	0
C&O-Ches	0	0	30	10	0	0	14	23
C&O-PM	0	0	4	1	0	0	0	0
C&EI	0	0	11	0	0	0	27	0
C&NW	70	9	481	57	0	14	78	37
CB&Q	2	1	9	0	0	0	53	73
CI&L	27	7	21	21	4	0	4	6
CMStP&P	247	8	212	19	1	1	10	0
CRI&P	0	0	71	0	0	0	60	1
C&S	0	1	0	0	0	0	0	0
D&H	0	0	11	0	0	0	5	2
DL&W	0	0	2	0	0	0	0	0
D&RGW	0	0	11	10	0	0	3	20
GTW	11	31	24	3	1	0	18	0
GN*	133	0	102	0	3	0	36	0
KCS	0	1	7	2	0	0	3	1
L&HR	0	0	8	0	0	0	0	0
L&NE	0	0	7	0	0	0	0	0
LV	0	0	21	0	0	0	0	0
LI	0	0	0	22	0	0	0	0
L&N	295	209	73	0	204	86	46	0
Me Cen	13	15	1	1	0	0	0	0
Mich Cen	5	5	13	1	3	1	22	3

TABLE 8 (Cont.)
RAIL FAILURES IN THE WEB WITHIN THE JOINT BAR LIMITS FOUND IN 1953
ON RAIL OF 100 LB. AND ALL HEAVIER SECTIONS

Railroad	Rail Rolled Previous to 1937				Rail Rolled in 1937 and after			
	Detected Failures		Service Failures		Detected Failures		Service Failures	
	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other	Bolt Hole	Other
MStP&SSM	65	3	24	6	0	0	1	1
MKT	0	0	2	0	0	0	0	0
MP RR	0	0	16	35	0	0	45	31
NC&StL	0	0	1	1	0	0	4	3
NYC-B/4	0	0	33	66	129*	19*	27	146
NYC-East	49	50	118	49	693	261	134	111
NYC-West	39	40	151	96	326	135	83	59
NYC&StL	0	0	41	0	12	0	163	16
NYNH&H	146	244	99	0	11	64	30	2
N&W	1	13	4	5	2	33	4	13
NP	161	152	422	265	0	0	81	93
PRR	641	259	1707	306	922	1011	288	132
P&LE	1*	1*	0	2	49*	65*	6	5
Reading	3	14	9	5	1	0	0	0
RF&P	0	0	0	0	0	268	0	0
StL-SF	122	39	0	13**	0	0	0	8**
SAL	7	10	15	7	8	8	27	2
Southern Sys	76	55	0	0	2	10	0	0
SP	31	1	4	3	176	3	9	35
T&NO	10	73	80	97	0	0	6	12
T&P	16	18	1	2	28	31	7	6
UP	35	50	3	2	59	148	7	3
Virginian	6	7	1	2	1	5	3	3
W Md	0	0	2	0	0	0	16	2
Totals	2424	1496	3974	1170	2765	2846	1538	900

* Found by audigage

** All bolt hole breaks and other separations have been grouped together

TABLE 9 - ACCUMULATED TRANSVERSE FISSURE FAILURES IN CONTROL COOLED RAIL AS VERIFIED BY LABORATORY INVESTIGATION, BY ROAD, MILL AND YEAR ROLLED TO OCTOBER 1, 1954

Roads	Mills	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	Total
CP	Algoma					1 (b)	1 (a)	1 (b)					2 (b)		1 (b)	2 (b)			8
Mich. C.	Algoma					1 (b)			1 (b)										2
PM	Algoma						1 (a)												1
NYNH&H	Carnegie(ET)			1 (c)															1
N&W	Carnegie(ET)					1 (a)				1 (c)									2
AT&SF	Colorado					1 (c)													1
CN	Dominion						1 (b)												1
C&NW	Gary		3 (b)	2 (b)															5
CB&Q	Gary		3 (b)																3
GN	Gary		1 (b)																1
NYC	Gary				1 (b)														1
Wabash	Gary			1 (b)															1
AT&SF	Inland							2 (a)											2
CB&Q	Inland									1 (a)	3 (a)								4
C&O	Inland	1 (a)	3	3 (a)	3			6 (a)			1 (a)	1 (a)						1 (a)	19
CMStP&P	Inland										2 (a)								2
CRI&P	Inland												1 (a)						1
UP	Inland					3 (a)	3 (a)												6
B&M	Lackawanna										1 (a)								1
C&O	Lackawanna															1 (a)			1
LV	Lackawanna								3 (a)	1 (a)									4
NYC	Lackawanna								1 (a)	1 (a)	2 (a)								4
NYC&StL	Lackawanna								2 (a)		2 (a)			2 (a)	1 (a)				7
AT&SF	Steelton			3 (a)															3
B&O	Steelton						1 (a)	1 (a)	2 (a)	1 (a)	1 (a)	1 (a)	1 (a)					1 (a)	9
P&M	Steelton						2 (a)		1 (a)										3
C of NJ	Steelton									1 (a)									1
C&O	Steelton	5 (a)		1 (a)	4 (a)		3 (a)						1 (a)			1 (a)			15
D&H	Steelton				1 (a)	2 (a)	1 (c)		1 (a)	1 (a)									6
MP	Steelton			1 (a)															1
N&W	Steelton					1 (a)	3 (a)		7 (a)					1 (a)					12
NYNH&H	Steelton			3 (a)		2 (a)	1 (a)		1 (a)	2 (a)									9
PRR	Steelton		2 (a)																2
RF&P	Steelton			1 (a)			1 (a)								2 (a)				4
SAL	Steelton							2 (a)		1 (a)									3
So Ry	Steelton							1 (a)		1 (a)									2
SP	Steelton		18 (a)	3 (a)	6 (a)	5 (a)	1 (a)												33
T&NO	Steelton		2 (a)	1 (a)															3
Va.	Steelton						2 (a)	1 (a)	1 (a)										4
C of Ga.	Tennessee									1 (c)									1
L&N	Tennessee							1 (c)											1
SP	Tennessee		1 (b)																1
TOTAL		6	33	20	15	17	21	15	20	12	12	2	5	3	4	4	0	2	191

TABLE 9 (Cont). - SUMMARY BY MILLS

Mills	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	Total
Algoma					2	2	1	1				2		1	2			11
Carnegie (ET)			1		1				1									3
Colorado	*				1													1
Dominion						1												1
Gary		7	3	1														11
Inland	1	3	3	3	3	3	8		1	6	1	1					1	34
Lackawanna								6	2	5			2	1	1			17
Steelton	6	22	13	11	10	15	5	13	7	1	1	2	1	2	1		1	110
Tennessee		1					1		1									3
TOTAL	6	33	20	15	17	21	15	20	12	12	2	5	3	4	4	0	2	191

Note: (a) TRANSVERSE FISSURE from hot torn steel. (b) TRANSVERSE FISSURE from shatter cracks due to improper cooling (c) TRANSVERSE FISSURE from inclusion. Summary - 22 T. F.'s from shatter cracks, 6 T. F.'s from inclusions, 163 T. F.'s from hot torn steel.

*No cc rail rolled.

found in 1953 in rail of 100 lb per yard or over, separated between that rolled prior and subsequent to 1937. The data are also shown separately for service and detected failures, and for bolt hole and other web cracks.

This table shows that 17,113 rails, equivalent to 63.5 track miles, were removed in 1953 because of this type of failure. A few large roads have reported the majority of the failures. It is interesting to note that several moderate size roads have reported very few failures of this type.

If, as is indicated, the cause of web failures has been corrected by measures now taken, this leaves detail fractures from shelling as the principal remaining rail problem.

All failures in control-cooled rail that are thought to be transverse fissures are sent to the University of Illinois for verification by Prof. R. E. Cramer as a part of the cooperative Rail Failure Investigation sponsored jointly by the AAR and the AISI. Table 9 has been prepared by Prof. Cramer to show the results to date of his examination of such rails. It will be noted that most of the failed rails sent to him were found to be transverse fissures from hot torn steel (a condition found to result from reheating blooms to too high a temperature). No transverse fissure from improper control-cooling has been reported in rail rolled in United States mills since 1939, a very remarkable record.

Report on Assignment 4

Rail End Batter: Causes and Remedies

K. K. Kessler (chairman, subcommittee), C. J. Code, B. R. Meyers, A. P. Talbot, E. L. Anderson, B. Bristow, R. M. Brown, B. Chappell, W. J. Cruse, J. K. Gloster, R. L. Groover, J. C. Jacobs, L. R. Lamport, C. C. Lathey, H. S. Loeffler, E. E. Mayo, E. E. Oviatt, G. L. P. Plow, G. W. Powrie, R. B. Rhode, J. G. Roney, J. C. Ryan, G. L. Smith, R. P. Winton, J. E. Yewell.

This is a progress report, presented as information.

Work has been started at the AAR Research Center on the evaluation of various welding methods and rods in the repair of battered rail ends.

Matched rail ends of 131 RE section having 0.030-in to 0.040-in batter have been repaired in duplicate by the following methods:

1. Welding Procedure Used

A. Acetylene Welding.

1. Use one manufacturer's rod; no grinding; no preheating; no post heating or quenching.
2. Use same rod as in 1; prepare weld area by grinding; no preheat except as required for welding; finish with flatter; no post heat or grinding.
3. Use the same procedure as in 2, except finish by means of grinder rather than a flatter.

2. Test Procedures to be Used

A. Equipment.

1. 12-in stroke rolling-load machine.
2. 30,000-lb wheel load.
3. New oversize head-contact joint bars or headfree joint bars which give a good fishing surface fit.
4. ⅜-in joint gap and 15,000-lb bolt tension.

B. Tests.

1. Make tests in duplicate.
2. Number of cycles to be determined by amount of batter, probably to 0.040 in at ½-in point.
3. Take top of rail profile at start and at suitable intervals.
4. Metallurgical Tests
   (a) Take Brinell hardness tests on each rail end about 1 in from end before and after rolling-load test.
   (b) Make macrographs on transverse sections.

Report on Assignment 5

Economic Value of Various Sizes of Rail

A. A. Shillander (chairman, subcommittee), E. L. Anderson, W. J. Burton, B. Chappell, C. J. Code, R. A. Emerson, P. O. Ferris, W. H. Hobbs, J. C. Jacobs, N. W. Kopp, W. B. Leaf, E. E. Mayo, B. R. Meyers, Embert Osland, R. E. Patterson, G. A. Phillips, R. B. Rhode, J. G. Roney, J. C. Ryan, J. F. Shaffer, W. D. Simpson, A. P. Talbot, J. S. Wearn.

Your committee submits the following report of progress as information. It is a continuation of maintenance charges in Study A for last year, computed to show average of 10 years.

Study A

RESULT OF STUDY OF ILLINOIS CENTRAL RAILROAD NORTHWARD TRACK MATTOON TO SAVOY, ILL. TEST SECTIONS OF 112-LB AND 131-LB RAIL

112-Lb Rail

M.P. 163.68 to M.P. 172.73 (Laid in 1942)
M.P. 152.24 to M.P. 163.68 (Laid in 1943)
(Station 10142+58 to Station 11224+95)
Total track miles maintained
(108,173 track feet) 20.48
No. turnouts maintained 18
No. railroad crossings maintained ... 1
No. public grade crossings maintained. 22
No. private grade crossings maintained 2
Joint bars 24 in
Tie plates 11 in by 7¾ in
Removed 8.05 track miles 7–1–53
Removed 4.03 " " 6–1–54
Remaining 8.40 " "

131-lb Rail

M.P. 132.00 to M.P. 152.24 (Laid in 1944)
(Station 11224+95 to Station 11293+98)
Total track miles maintained
(106,747 track feet) 20.21
No. turnouts maintained 21
No. railroad crossings maintained ... 3
No. public grade crossings maintained. 22
No. Private grade crossings maintained 6
Joint bars 36 in
Tie plates 13 in by 7¾ in

Both Test Sections Computed at 1944 Prices

Average Annual Traffic Density—28,000,000 Gross Tons

Rail and Other Track Material	Investment Charges Per Mile			
	112 Lb		131 Lb	
Gross cost	$12,643		$14,413	
Less est. salvage	Cr. 4,284		Cr. 5,011	
Net cost	8,359		9,402	
Total cost to lay	1,338		1,473	
Total cost to place	9,697		10,875	
Estimated life—years	15		25	
Annual Cost				
Rail and other track material		$ 557		$ 376
Laying		89		59
*Interest at 6%		839		953
Total annual cost		$1,485		$1,388
Percent decrease in investment cost	----	----	----	Cr. 6.5

*On gross outlay for material and labor.

Comparison of the Test Sections—Labor and Materials

112-Lb Rail						131-Lb Rail					
Year	Man-Hours	Cross Ties	Switch Ties	Ballast Cu Yd	Rail Failures	Year	Man-Hours	Cross Ties	Switch Ties	Ballast Cu Yd	Rail Failures
1942											
1943	49,427	14,148	3-#10-0	12,419	----	1944	52,742	21,555	5-#10-0	13,102	----
1944	8,165	102	1-#15-0	337	----	1945	2,643	----	----	600	----
1945	13,842	4,665	----	4,958	----	1946	7,582	91	----	2,300	----
1946	23,046	8,221	----	11,450	----	1947	15,137	3,478	----	6,100	----
1947	12,746	4,101	1-#15-0	5,400	1	1948	5,961	764	1-#10-0	3,750	----
1948	19,855	3,671	----	5,800	----	1949	13,570	200	1-#10-0	2,350	----
1949	31,106	10,687	3-#10-0	8,350	3	1950	32,995	8,083	----	6,840	----
1950	13,818	3,466	2-#10-0	3,160	9	1951	12,333	1,193	----	1,050	----
1951	12,277	952	----	3,850	5	1952	22,734	1,243	3-#10-0	6,100	----
1952	11,406	451	----	2,135	----	1953	21,875	2,792	2-#10-0	2,415	----
Total	195,688	50,464		57,859			187,572	39,399		44,607	

Average of 10 Years

Annual Cost	Maintenance Charges Per Mile					
	112 Lb 20.48 Mi	Percentage	131 Lb 20.66 Mi (T)	Percentage	Savings by Use of 131 Lb	Percentage
Man-hours	956	----	908	----	48	----
Cost at $1.06	$1,013	52.6	$ 962	57.7+	$ 51	19.8
Cross ties	246	----	191	----	55	----
Cost at $2.67	$ 656	34.1	$ 509	30.5+	$147	56.9
Ballast (stone) tons	316	----	242	----	74	----
Cost at $.81	$ 256	13.3	$ 196	11.7+	$ 60	23.3
Total maintenance	$1,925	100.0	$1,667	99.9+	$258	100.0
Percent	----	----	----	----	13.4	----
Investment charges	$1,485	----	$1,388	----	----	----
Total cost	$3,410	----	$3,055	----	$355	----
Percent	----	----	----	----	10.4	----

(T) Adjusted for additional turnouts and crossings. Prices are the average of 10 years.

Summary

Both rails, except the 112-lb removed, are in good condition; however, the 131-lb appears to be better in straightness, and to have less wear and a better joint condition. The joint bars on the 112-lb show considerable wear and will be replaced by reformed or new bars.

The original estimate of service life in first location, anticipating 15 years for 112-lb and 25 years for 131-lb, has been carried through this report, however, present indications are that some revision of this anticipated life may be necessary in future reports.

Eight miles of 112-lb, in which joint packing had been installed, were removed on account of an excessive number of bolt hole failures. Four miles of 112-lb, in another stretch of track, were removed on account of damage by engine burns. There remain, therefore, only 8.40 miles in track.

All of the 131-lb is in track as laid.

It is worth special notice that the greatest saving through the use of 131-lb rail is in ties. This is likely due to the use of longer and heavier joint bars and tie plates with this rail, and to the greater rigidity of the rail itself.

Report on Assignment 6

Service Tests of Various Types of Joint Bars

T. A. Blair (chairman, subcommittee), W. J. Burton, B. Chappell, L. S. Crane, C. J. Code, J. C. Jacobs, J. C. De Jarnette, P. O. Ferris, R. L. Groover, K. K. Kessler, N. W. Kopp, W. B. Leaf, H. S. Loeffler, E. E. Mayo, B. R. Meyers, E. H. McGovern, Embert M. Osland, G. A. Phillips, G. L. P. Plow, E. F. Salisbury, J. F. Schaffer, S. H. Shepley, G. L. Smith, J. S. Wearn, R. P. Winton.

This is a progress report, presented as information. The field work, analysis of data, and report of the measurements covered in this report were carried out by Kurt Kannowski, metallurgical engineer, and other members of the Engineering Division research staff of the Association of American Railroads, under the direction of G. M. Magee, director of engineering research.

Description of 1948 Service Installations

The report of the committee in 1949 described the two service installations of various types of joint bars for the new 115 and 132 RE rail sections. Subsequently, at the request of the Rail Joint Company, an additional joint bar design of the long-toe or angle-type was added to each of the two installations. The service test sections of 132 RE joint bars are located on the eastbound main track of the Atchison, Topeka & Santa Fe Railway, 100 miles west of Chicago. Each test section is ½ mile in length, all located on tangent track. The test installation includes the following different test sections:

- Location V—132 headfree, 36 in, 6–6–7⅛–6–6 in, new AREA punching, 6-hole bars, placed in August 1948.
- Location W—132 RE headfree, 36 in. 9–9⅛–9 in punching, 4-hole bars, placed in August 1948.
- Location X—132 RE headfree, 36 in, 6½–6½–5⅛–6½–6½ in, old AREA punching, 6-hole bars, placed in August 1948.
- Location Y—132 Rail Joint Co., K-42, headfree, 36 in, 6½–6½–5⅛–6½–6½ in, old AREA punching, 6-hole bars, placed in March 1949.

Location Z—132 Rail Joint Co., K-44, headfree, long-toe design, 39 in, 6½–6½–5⅛–6½–6½ in, old AREA punching, 6-hole bars, placed in March 1949.

It will be observed from the above that this test installation for 132 RE rail includes a comparison of three different designs of joint bars, and in the case of the new AREA head-free joint bar includes three different bolt hole spacings. Fig. 1, page 572 of AREA Proceedings, Vol. 51, 1950, shows the exact location of each test section, tied into mile posts and highways, and includes the designation letter and description of each.

In October 1948 measurements were made of rail surface profile, joint camber and out-to-out distances of bars on locations V, W and X to provide base measurements for determining the rate of rail-end batter, joint droop, and fishing surface wear. Corresponding measurements were made at location Y and X in May 1949 and October 1949, respectively. Complete measurements were made in July 1950, June 1951, May 1953, and May 1954. The results of all of these tests are shown on Figs. 1, 2 and 3. In order to avoid confusion on Fig. 3 the measurements of May 1948, June 1951 and May 1954 are shown. At the time of the May 1954 measurements the test track had carried 93 million gross tons of traffic during the test period.

The test sections of the new 115 RE rail were installed on the westbound main track of the Chicago & North Western Railway near Sterling, Ill., 106 miles west of Chicago, on the Omaha line. Each test section includes 100 joints and is approximately 2000 ft long. Location EE, the long-toe or angle-bar design, was added in May 1949, the other sections having been placed in November 1948. This test installation now includes the following sections, all on tangent track.

Location AA—115 RE headfree, 36 in, 9–9⅛–9 in punching, 4-hole bars.

Location BB—115 RE headfree, 36 in, 6–6–7⅛–6–6– in, new AREA punching, 6-hole bars.

Location CC—115 R. J. Co., K-22, headfree 36 in, 6–6–7⅛–6–6 in, new AREA punching, 6-hole bars.

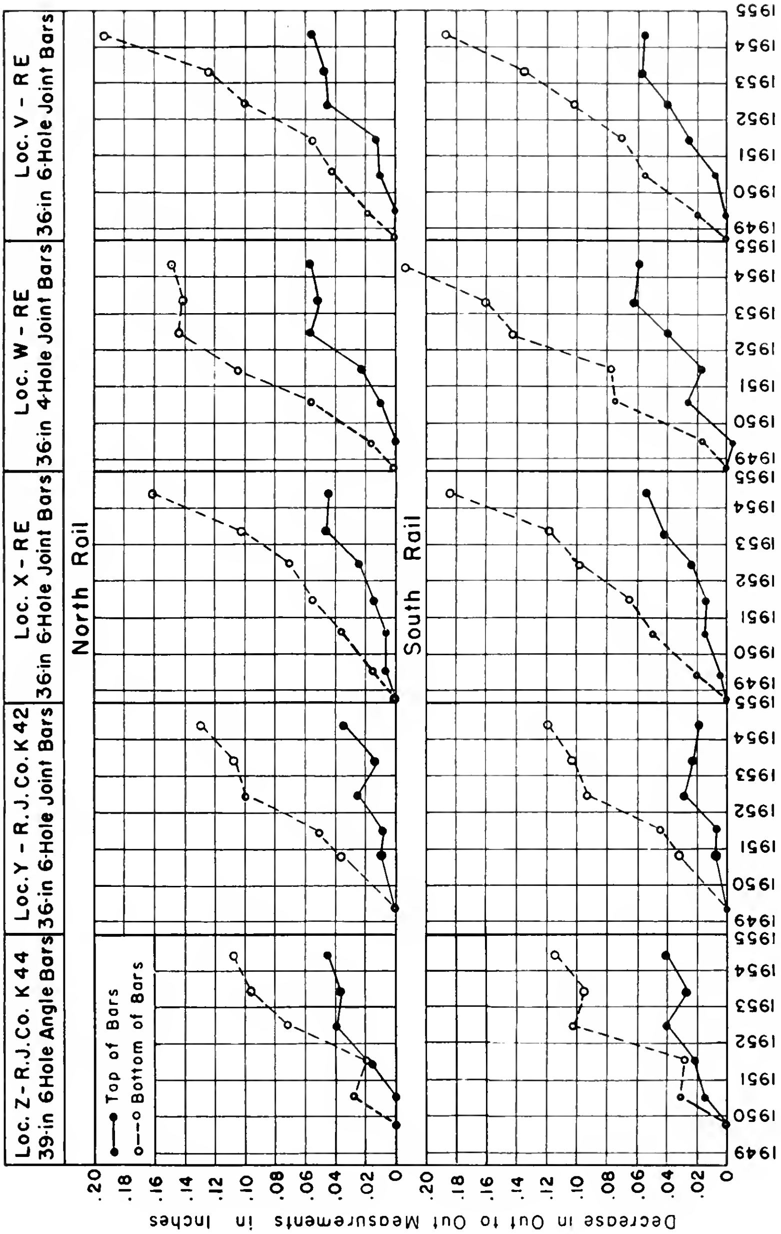
Location DD—115 R. J. Co., K-4, headfree, 36 in, 6–6–7⅛–6–6 in, new AREA punching, 6-hole bars.

Location EE—115 R. J. Co., K-24, headfree, long-toe design, 39 in, 6–6–7⅛–6–6 in, new AREA punching, 6-hole bars.

The designation letters for locations AA to DD are the reverse of the order given in the report of 1949. This change was made after location EE was added to have the sections in alphabetical order in track.

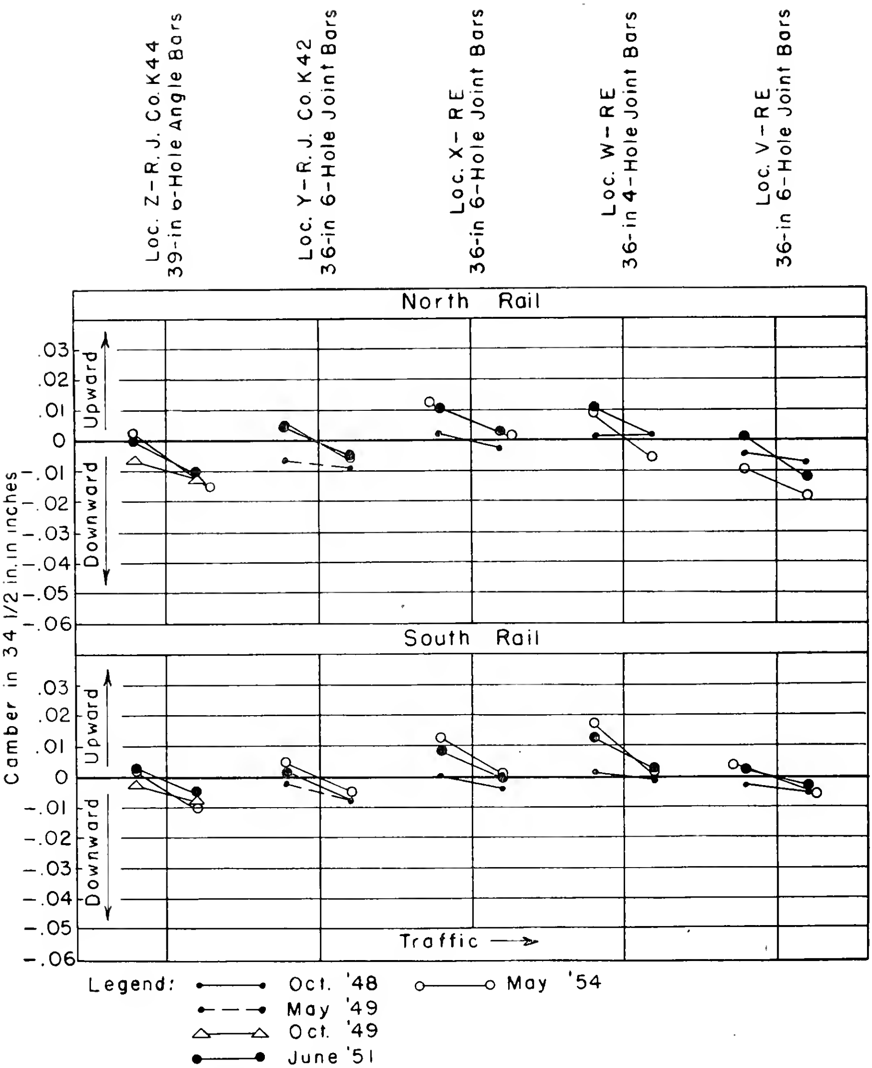
It will also be noted that the above includes four different designs of joint bars and also includes for the new 115 AREA headfree design a test section with the new AREA punching and a test section with a 4-hole punching for a 36-in length bar. Fig. 2 on page 573 of AREA Proceedings, Vol. 51, 1950, shows mile posts, highways, designation letters, and joint bar description relative to each test section. Measurements of rail surface profile, joint camber, and out-to-out distances of bars were made in May 1949, May 1950, May 1951, June 1953 and June 1954. The results of these measurements are shown on Figs. 4, 5 and 6. On Fig. 6 the measurements of May 1949, July 1952 and June 1954 are shown only in order to avoid confusion. At the time of the June 1954 measurements, the test track had carried 108 million gross tons of traffic during the test period.

(Text continued on page 937)



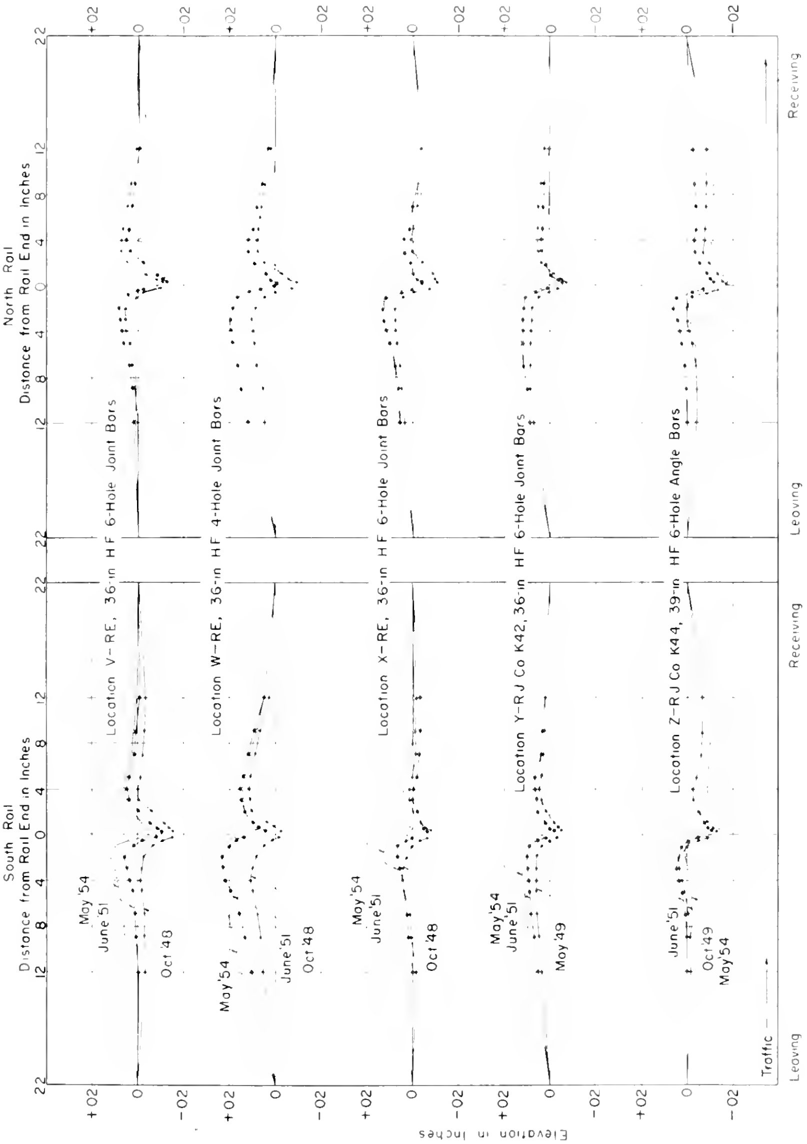
Note: Out-to-Out measurements are the average of 30 joints on each rail at all test locations.

Fig. 1 — Change in Out-to-Out Distances at Middle of Joint Bars, A T & S F Ry.



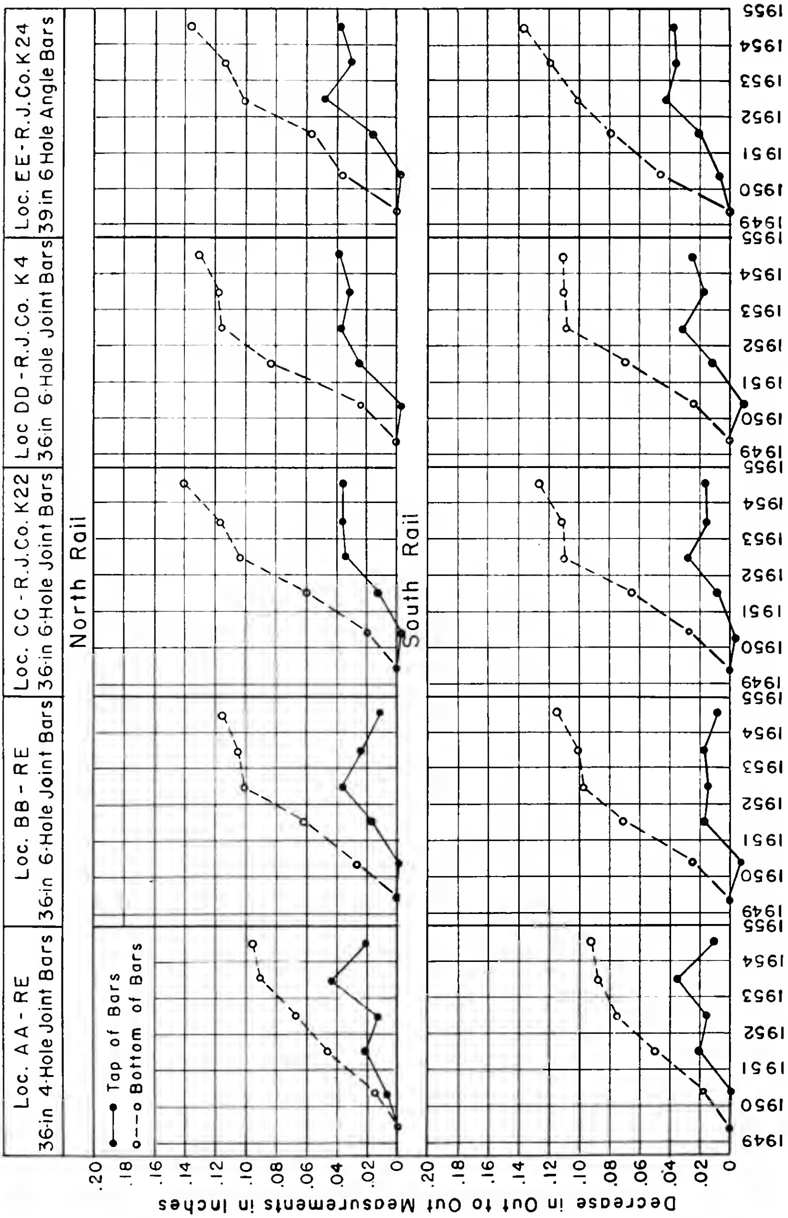
Note: Camber readings are the average of 30 joints each of North and South rail at all test locations, taken 1/2 in. from rail ends.

Fig. 2 — Top of Rail Camber in 34 1/2 in., A.T. & S.F. Ry. 1948 to 1954



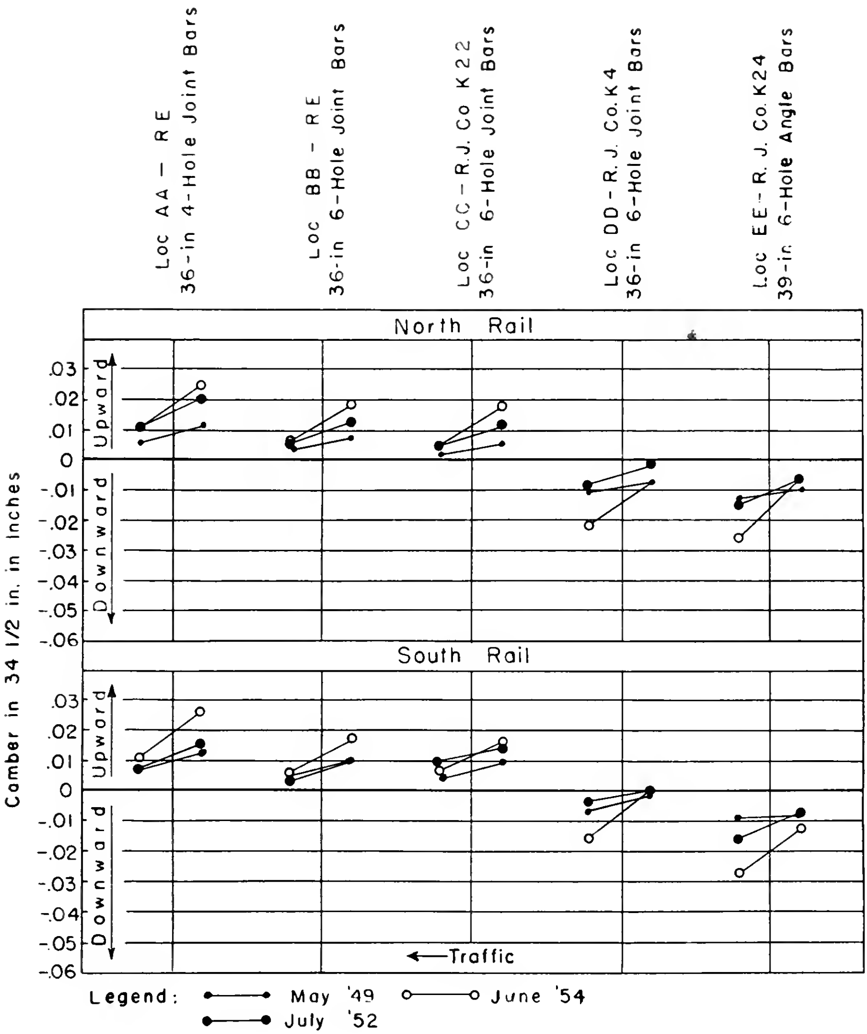
Note Profile elevations are the average of 15 joints of each rail

Fig 3—Rail Surface Profile, AT&SF Ry, 1948 to 1954



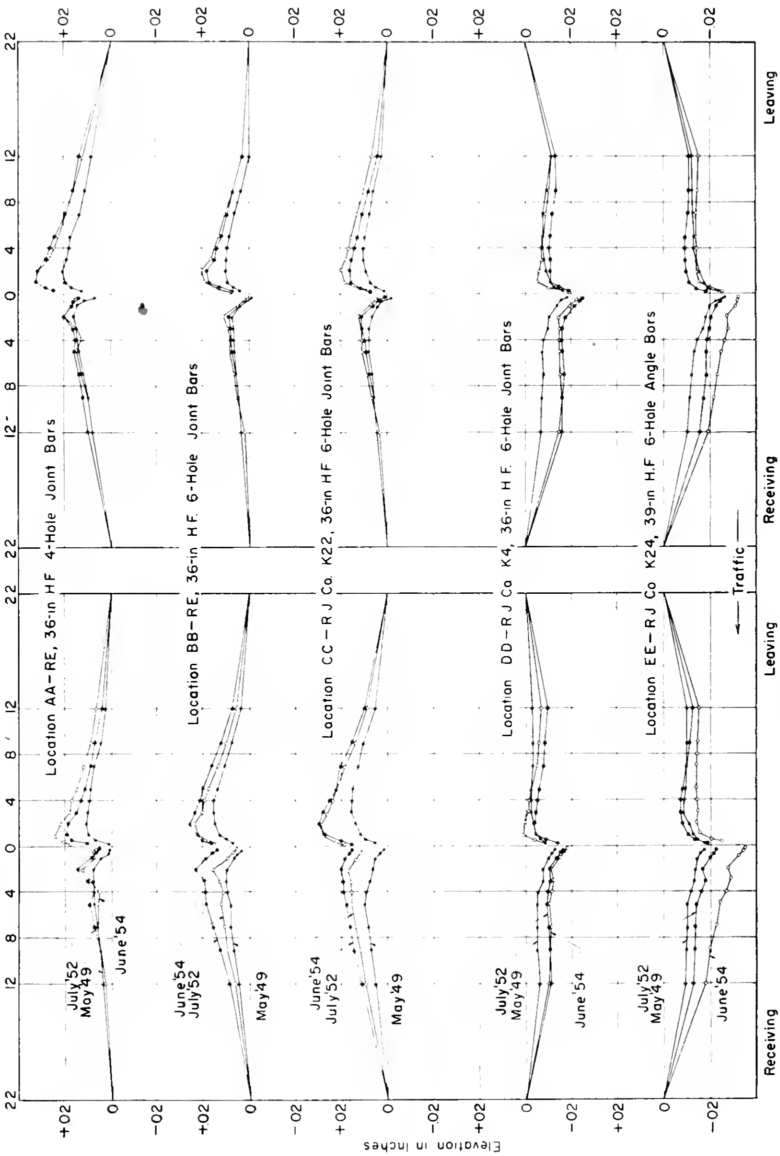
Note: Out-to-Out measurements are the average of 30 joints on each rail at all test locations.

Fig. 4— Change in Out-to-Out Distances at Middle of Joint Bars, C & N W Ry.



Note: Camber readings are the average of 30 joints each of North and South rail of all test locations, taken 1/2 in. from rail ends.

Fig. 5 - Top of Rail Camber in 34 1/2 in., C&NW Ry. 1949 to 1954



Note: Profile elevations are the average of 15 joints of each rail.

Fig. 6—Rail Surface Profile, C.&N.W. Ry. 1949 to 1954

Discussion

The performance of the different types of joint bars, as shown by Figs. 1 to 6, has been normal to date. In general, the decrease in out-to-out distance, shown in Figs. 1 and 4, for the bottom of the bars seems to be following a trend of a constant rate per year, with occasional variations one way or the other. Since the bars are all of the head-free type, most of the pull-in occurs at the bottom of the bars.

On the Santa Fe test the RE design bars show a greater amount of pull-in than the K44 or K42 designs. Much of this is due to the fact that the RE bar measurements represent a year longer service compared to the K44 bars, and 8 months longer service compared to the K42 bars. The RE bars showed a greater than normal amount of pull-in this year. It will be interesting to see if this continues or is merely a variation from the general trend that will compensate next year.

With respect to joint droop, on the Santa Fe test there is no significant change in any of the test sections. Generally, the tendency is toward a joint hump rather than a droop. On the C&NW test, the RE bars are showing this same humping tendency, whereas the K4 and K22 bars are showing some droop, especially at the receiving rail end.

The rail surface profile for all of the test sections looks very good. On the Santa Fe test, location X and the south rail of locations Y and Z have the least amount of batter. Location W, with the 4-hole bars, has somewhat more batter and humping than the other sections, but its performance is still good.

On the C&NW test installation, the amount of batter is about the same for all test sections. The K4 and K24 sections have low profiles, whereas all of the others are high. This is largely due to the initial camber of the bars when new.

Conclusions

After six years of service all of the test sections are showing excellent performance and there is no significant difference in the performance of any of them.

Report on Assignment 7

Joint Bar Wear and Failures; Revision of Design and Specifications for New Bars, Including Insulated Joints and Bars for Maintenance Repairs

Embert Osland (chairman, subcommittee), T. A. Blair, W. J. Burton, C. J. Code, L. S. Crane, J. C. DeJarnette, J. L. Gressitt, R. L. Groover, W. H. Hobbs, S. R. Hursh, L. R. Lamport, E. E. Mayo, E. H. McGovern, B. R. Meyers, G. A. Phillips, G. L. P. Plow, J. C. Ryan, I. H. Schram, J. F. Shaffer, S. H. Shepley, A. P. Talbot, H. F. Whitmore.

This is progress report, submitted as information.

The principal work on the assignment during the past year has been the continuation of the rolling-load tests of joint bars being conducted at the University of Illinois under the direction of Professor R. S. Jensen. The results of these tests are submitted in Appendix 7–a.

Appendix 7–a

Thirteenth Progress Report of the Rolling-Load Tests of Joint Bars

By R. S. Jensen

Research Assistant Professor of Engineering Materials, University of Illinois

Introduction and Acknowledgment

This report covers tests of joint bars conducted during the past year in the Talbot Laboratory, University of Illinois, as a part of the work of the Engineering Experiment Station in cooperation with the American Railway Engineering Association's Committee on Rail under Assignment 7—Joint bar wear and failures; revision of design and specifications for new bars, and bars for maintenance repairs. Embert Osland, office engineer, Atchison, Topeka and Santa Fe Railway, is chairman of the subcommittee for this assignment. The work is sponsored and financed by the Association of American Railroads.

Acknowledgment is made of the services of James Bryant and Elmer Hunt, mechanicians in the Talbot Laboratory shops.

Testing Machines and Test Specimens

Joint bar tests were made in three 33-in stroke rolling machines similar to the one described in the Proceedings, Vol. 40, 1939, page 649. The dimensions of the test joint and method of loading are described in the Proceedings, Vol. 44, 1943, page 587. In all tests, the maximum bar bending stresses are obtained with the wheel load at the joint gap and are 50 percent in value and reversed in sign with the wheel load at the cantilever end of the stroke. The criterion for bar failure is taken to be the number of cycles of loading to propagate a fatigue crack to one-half of the bar height.

Results of Rolling Load Tests

Thirty-six tests on 132 RE headfree 36-in bars have been completed since the last annual report was published. Twelve tests (joints 292 to 303) were on new bars, originally with a pressed easement, which had the easement ground to a depth of $\frac{3}{32}$ in and a length from 1½ to 1⅝ in to eliminate decarburization. The chemical analyses of the heats from which these bars were rolled are as follows:

Serial 144, Heat 10–189, C–0.47, Mn.–0.71, P–0.017, S–0.038, Si–0.14
Serial 145, Heat 7–166, C–0.52, Mn.–0.83, P–0.017, S–0.022, Si–0.30

Twelve tests (joints 304–315) were on used bars which had been reheat treated after grinding easements to a depth of 3/64 to 7/64 in and to a length of 1⅛ to 1⅝ in. These bars were oil quenched from 1500 to 1550 deg F.

Twelve tests (joints 316–327) were on used bars which had been reheat treated after grinding easements to a depth of 1/32 to 5/64 in and to a length of 1 to $1\frac{7}{16}$ in. The bars were oil quenched from 1500 to 1550 deg F and tempered at 800 deg F. Data on these 36 joints are tabulated in Table 1, and physical properties, as determined by tensile tests on specimens cut from each failed bar, are listed in Table 2. All of the bars tested had the old bolt hole spacing of 5⅛ in between central holes and 6½ in between remaining holes.

(Text continued on page 942)

Table 1—Rolling-Load Tests of Joint Bars

Maximum Positive Bending Moment: 55,500-lb load—500,000 in-lb.
Maximum Negative Bending Moment is 50 percent of positive moment.
Bolt Tension: 15,000 lb; Bolt: 1⅛ in diameter, heat treated, prestressed.

Joint No.	Cycles For Failure	Bar Failure (N = North, S = South)	Surface Hardness Failed Bar, BHN	Hardness on Tensile Specimen, BHN	Depth of Decarb. from Micrograph, Inches	Pinching From Hot Sawed Rails on Failed Bar, Inches: Top	Bottom
Bars: 132 RE Headfree 36-In (Ground Easements) Serial 144 for Jts. 292–293, Serial 145 for Jts. 294–303							
292	339,800	Both Top —N— to bolt hole	N-210	245	0.010	0.006	0.004
		—S—⅝″ from rail end	S-213	238	0.012	0.024	0.004
293	295,100	N. Base —Rail end	241	239	Slight	0.011	0.004
294	274,300	S. Base —To bolt hole	212	255	0.012	0.010	0.002
295	409,600	S. Top —1½″ from rail end	211	253	0.008	0 005	0.004
296	294,900	S. Base —Rail end	237	249	0.009	0.015	0.016
297	411,000	N. Top —1⅝″ from rail end	218	247	0.008	0.004	0.005
298	995,900	Both —N. Top Rail end	N-244	256	0.010	0.011	0.005
		—S. Base 4½″ from rail end	S-255	261	0.008	0.019	0.006
299	434,500	S. Top —To bolt hole	235	251	0.010	0.015	0.005
300	423,900	N. Top —To bolt hole	261	249	Slight	0.004	0 004
301	345,000	N. Top —1½″ from rail end	232	250	0.012	0.000	0.005
302	239,800	S. Base —Rail end	213	250	0.009	0.028	0.007
303	379,600	S. Top —¾″ from rail end	231	251	0.006	0.016	0.005
	403,610	Average of 12 joints					
Bars: 132 RE Headfree 36-In (Used Bars Reheat Treated after Grinding Easements)							
304	1,170,300	N. Base —Rail end	226	262	0.008	0.002	0.005
305	939,900	S. Top —To bolt hole	228	232	Slight	0.010	0.004
306	785,400	N. Base —Rail end	221	231	Slight	0.002	0 003
307	1,382,800	N. Base —To bolt hole	229	237	Slight	0.004	0.002
308	559,200	S. Base —Rail end	241	241	Slight	0.009	0.007
309	1,029,400	N. Top —To bolt hole	227	237	Slight	0.003	0.002
310	840,800	S. Base —Rail end	214	242	0.010	0.017	0.007
311	359,100	S. Base —Rail end	228	235	Slight	0.020	0.006
312	311,800	N. Base —Rail end	204	244	0.005	0.005	0.007
313	750,200	S. Base —Rail end	254	231	Slight	0.012	0.010
314	403,200	N. Base —Rail end to bolt hole	187	201	0.012	0.008	0.007
315	610,400	N. Base —Rail end	236	235	0.005	0.017	0.005
	761,870	Average of 12 joints					

Table 1—Rolling-Load Tests of Joint Bars (Continued)

Joint No.	Cycles For Failure	Bar Failure N = North S = South	Surface Hardness Failed Bar, B H N	Hardness on Tensile Specimen, B H N	Depth of Decarb. from Micrograph, Inches	Pinching From Hot Sawed Rails on Failed Bar Inches: Top	Bottom
		Bars: 132 RE Headfree 36-In (Used Bars Reheat Treated—Oil Quenched and Tempered After Grinding Easements)					
316	566,500	N. Base —Rail end	217	241	Slight	0.013	0.002
317	362,900	S. Top —Rail end	237	255	Slight	0.015	0.006
318	305,600	S. Top —Rail end	172	213	0.013	0.017	0.008
319	510,900	S. Base —Rail end	248	255	0.008	0.012	0.005
320	405,100	S. Top —5/8″ from rail end	232	260	0.005	0.015	0.008
321	249,500	N. Base —Rail end	186	223	0.007	0.003	0.003
322	553,300	S. Top —3/4″ from rail end	197	212	0.015	0.015	0.008
323	353,300	N. Base —To bolt hole	224	230	0.011	0.002	0.008
324	860,500	N. Base —To bolt hole	251	260	0.011	0.004	0.005
325	1,116,300	N. Base —Rail end	215	255	0.006	0.003	0.005
326	291,300	S. Top and Base—1 1/2″ from rail end	Top 176 Base 185	255	0.006	0.009	0.003
327	244,600	S. Top —To bolt hole	206	262	0.012	0.009	0.003
	484,980	Average 12 joints					

Table 2—Physical Properties of Laboratory Joint Bars

Bar Type	*Joint Number*	*Surface Hardness, B H N*	*Hardness on Tensile Specimen, B H N*	*Yield Point, Psi*	*Tensile Strength, Psi*	*Reduction of Area, Percent*	*Elongation 2-In Gage Length, Percent*
132RE HF	292N	210	245	74,000	117,100	15.4	18.0
"	292S	213	238	74,400	117,000	48.0	19.0
"	293N	241	239	75,100	119,800	44.8	18.0
"	294S	212	255	79,000	125,000	41.8	17.0
"	295S	211	253	79,500	126,000	43.0	17.0
"	296S	237	249	78,800	124,000	44.9	17.0
"	297N	218	247	78,300	122,000	46.4	18.0
"	298N	244	256	80,200	126,500	43.5	16.5
"	298S	255	261	81,000	128,800	11.5	16.5
"	299S	235	251	76,200	124,200	43.0	17.0
"	300N	261	249	81,400	127,400	45.1	17.5
"	301N	232	250	78,500	125,000	13.0	17.0
"	302S	213	250	80,800	127,000	44.7	17.5
"	303S	231	251	79,000	125,000	45.4	18.0
The following five specimens were machined from the base of the bars							
"	293N	241	259	82,000	126,000	46.4	18.0
"	294S	212	255	81,500	128,000	42.5	17.0
"	296S	237	265	80,400	126,000	47.4	18.0
"	298S	255	258	78,600	126,200	10.3	16.0
"	302S	213	257	80,100	127,000	12.8	17.5
132RE HF	304N	226	262	81,000*	121,500	33.2	15.0
"	305S	228	232	72,500	119,200	41.8	17.0
"	306N	221	231	69,500	116,500	39.5	17.0
"	307N	229	237	71,000	114,600	46.0	19.0
"	308S	241	241	72,000	117,200	43.5	18.5
"	309N	227	237	70,000	118,800	43.0	17.5
"	310S	214	242	78,400*	120,000	35.2	15.5
"	311S	228	235	75,900*	117,300	34.8	16.0
"	312N	204	244	79,400*	121,600	32.0	15.0
"	313S	254	231	71,300	116,200	43.7	17.5
"	314N	187	201	58,700	102,800	43.6	19.0
"	315N	236	235	72,000	116,800	42.5	18.0
The following ten specimens were machined from the base of the bars							
"	304N	226	239	73,000	119,000	41.8	17.5
"	306N	221	236	71,000	118,200	37.6	16.5
"	307N	229	209	67,000	107,800	50.5	22.5
"	308S	241	209	68,400	104,800	57.4	25.0
"	310S	214	245	71,600	118,200	39.2	17.0
"	311S	228	242	70,500	114,000	43.6	18.5
"	312N	204	254	71,700	119,000	38.5	17.0
"	313S	254	253	70,300	114,800	45.7	19.0
"	314N	187	187	56,000	94,000	53.4	24.5
"	315N	236	204	63,800	104,000	54.7	24.0
132RE HF	316N	217	241	76,600*	118,600	29.8	14.0
"	317S	237	255	80,400*	122,000	29.7	14.0
"	318S	172	213	66,600	105,000	48.4	22.0
"	319S	248	255	84,500*	125,500	35.4	15.0
"	320S	232	260	84,800*	125,500	29.8	14.0
"	321N	186	223	65,000	110,000	45.8	19.0
"	322S	197	212	65,000	105,000	45.0	20.0
"	323N	224	230	72,200*	111,500	31.7	15.5
"	324N	251	260	82,500*	124,000	40.7	16.0
"	325N	215	255	78,700*	120,500	30.3	14.0
"	326S	176	255	77,400	124,200	45.0	17.0
"	327S	206	262	80,700	126,000	46.3	17.5
The following seven specimens were machined from the base of the bars							
"	316N	217	237	75,100*	117,200	35.5	16.0
"	319S	248	256	87,000*	128,000	32.2	14.5
"	321N	186	225	63,200	105,200	51.4	21.5
"	323N	224	250	71,700*	111,500	37.7	17.0
"	324N	251	272	83,500*	125,000	36.2	15.0
"	325N	215	260	75,800*	118,200	33.7	15.0
"	326N	185	271	83,300	130,000	42.7	16.0

*No well-defined yield point—value is yield strength.

AREA specifications: Tensile strength, min 100,000 psi
Yield point, min 70,000 psi
Elongation in 2 in, min 12 percent
Reduction of area, min 25 percent

Hardness Tests on Joint Bars

Both Brinell and Rockwell B hardness readings were taken on upper and lower fishing surfaces of all bars before testing, and Brinell readings were also taken on both ends of the tensile specimens cut from the center of the head of each failed bar.

For the new bars (joints 292–303), Brinell readings on the top surface ranged from 199 to 261, with an average hardness of 226; and readings on the lower fishing surfaces ranged from 212 to 290, with an average of 257 for 24 bars. Rockwell B readings, converted to equivalent Brinell, averaged 44 points lower for these bars.

For the reheat treated bars (joints 304–315), Brinell readings on the top surfaces ranged from 181 to 247, with an average of 213; and readings on the lower fishing surfaces ranged from 187 to 254, with an average of 225. Rockwell B readings converted to equivalent Brinell averaged 41 points lower for these bars.

For the reheat treated oil-quenched and tempered bars (joints 316–327), Brinell readings on the top surfaces ranged from 172 to 255, with an average of 212; readings on the lower fishing surfaces ranged from 185 to 255, with an average of 217. Rockwell B readings converted to equivalent Brinell averaged 40 points lower for these bars.

The tensile specimens machined from the heads of the 38 failed bars showed Brinell hardnesses ranging from 201 to 262, with an average hardness of 249 for the new bars, 235 for the reheat treated bars, oil quenched, and 243 for the reheat treated bars, oil quenched and tempered.

Rolling-Load Tests of New 132 RE Headfree Bars with Ground Easements

Results of 12 tests of new 132 RE headfree, 36-in bars with ground easements are given in Table 1. The average cycles for failure for these 12 joints is 403,610 cycles. This average is only about one-half as great as the average of 934,290 cycles for 12 tests of 132 RE bars without easements reported in 1952, and it is about the same as the average of 406,590 cycles for 12 tests of 132 RE bars with mill pressed easements (joints 280–291), reported last year. Since Brinells on the failed bars at the surface ranged from 210 to 261, with an average surface hardness of 229, and physical properties, as determined from the tensile tests, were well above specifications, it seems possible that the low average numbers of cycles may have resulted from imperfect fit of the bars on the rails, resulting in local areas of heavy bearing, severe enough to start a crack. Three of the fractures are shown in Fig. 1.

Fourteen bars of the 12 joints failed, both bars failing in joints 291 and 298. Nine of the failures were from the top and 5 were from the base, with 3 of the top failures progressing to oval bolt holes and one base failure progressing to a round bolt hole. Small fatigue areas about ⅛ in. in height were observed at 2 of the oval holes. Three of the base failures started in rail end gouges.

The ground easements on the top bar surfaces eliminated gouging by the rail ends, and with one exception bar failures from the top surfaces started outside of the easements in areas of heavy bearing. The exception was bar 298N, which cracked through the center of the easement, and probably failed after the other bar in this joint had broken.

Magnaflux examination revealed additional transverse cracks on the top fishing surfaces of 10 of the failed bars and 5 of the companion bars. The cracks, ranging in length from ⅛ in to 1⅛ in, occurred in heavy bearing areas within a few inches of the centers of the bars. Fig. 2 shows 3 of the bars with cracks which caused failure.

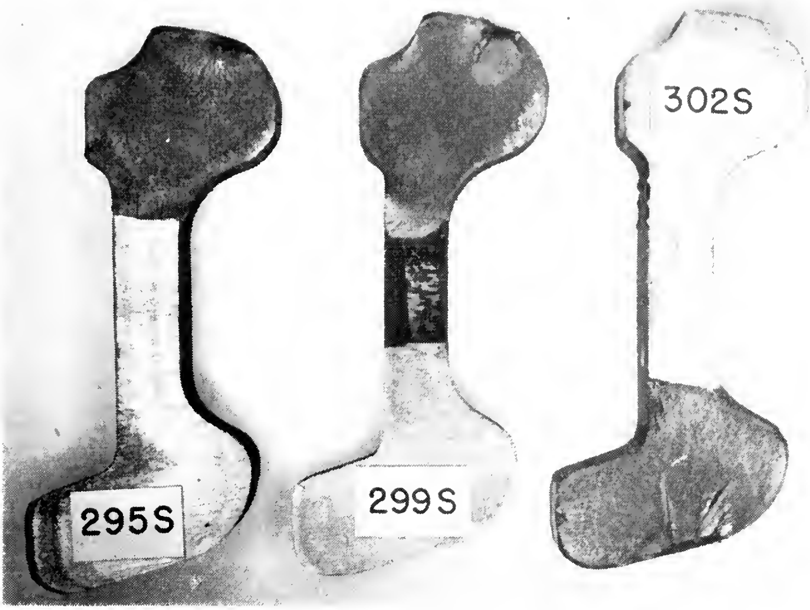


Fig. 1—Fatigue failures of 132 RE bars.

Micrographs were taken on specimens cut from each failed bar and revealed a fairly fine grain structure for all bars. Three micrographs, which are typical, are shown in Fig. 3. Some decarburization was noted, up to depths of 0.12 in for the failed bars.

Since tightening of the bolts was noted to bend the bars laterally at mid-length, lateral deflection readings were taken on upper and lower bar flanges before bolting, after bolting, and at regular intervals during the progress of each test. The amount of lateral bending varied with individual bars, and since unbroken bars recovered to their original shape upon release of bolt tension, it was apparent the bending was elastic.

Lateral deflection readings on the bars indicated that at 100,000 cycles the centers of the bars were bowed inward from 0.001 to 0.007 in, with an average of 0.003 in for the upper flanges. Bending on the lower flanges ranged from 0.006 to 0.020 in inward, with an average of 0.013 in.

Out-to-out measurements, that is, the distance between outer bar flanges, indicated that at 100,000 cycles the lower flanges had moved inward an average of 0.034 in at the center of bar length and 0.013 in average at the ends of the bars. The upper flanges averaged only 0.002 in movement at the center and 0.001 in at the ends.

The physical properties of the failed bars, as indicated in Table 2, were all above AREA specifications, both in tensile strength and yield point.

Rolling-Load Tests of Reheat Treated 132 RE Headfree Bars with Ground Easements

The results of 12 tests of 132 RE headfree used bars, reheat treated after grinding easements, are given in Table 1. The average cycles for failure for these 12 joints is 761,870 cycles.

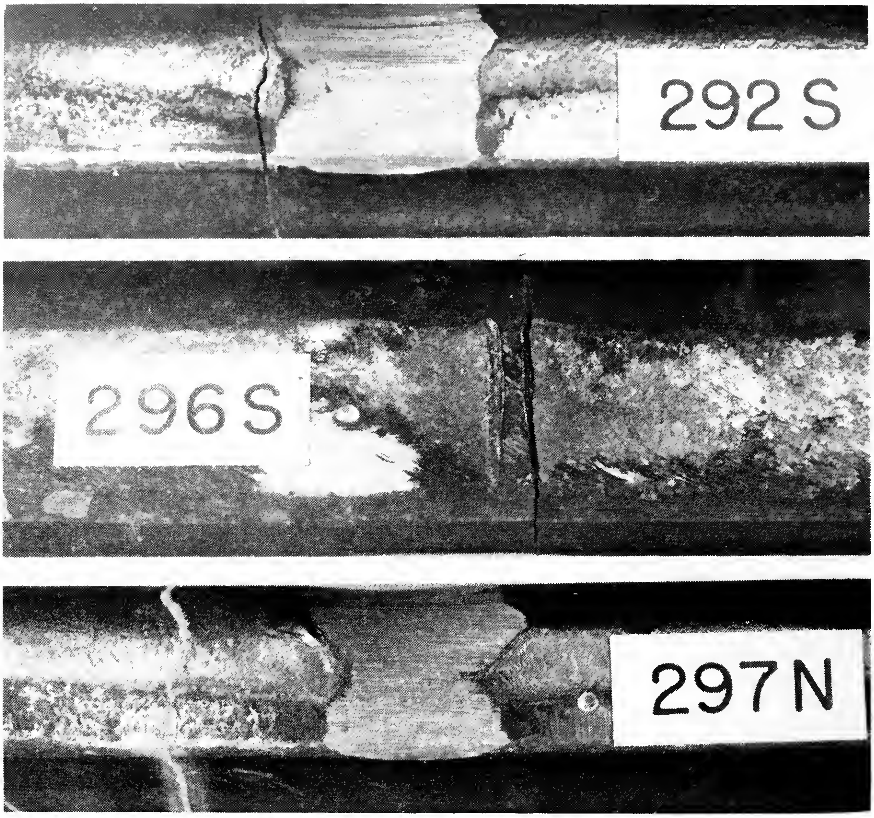


Fig. 2—Joint bar fishing surfaces with cracks.

Bars 292S and 297N show top surface. Bar 296S shows lower fishing surface with crack in gouge.

These bars (joints 304–315) were from a group of bars rolled in 1948 and removed from track in 1951 for inspection and salvage by special heat treatment. The bars were first inspected visually during the grinding of an easement with a beveled 8-in diameter resinoid grinding wheel. The ground easements varied from 3/64 to 7/64 in. in depth and from 1⅛ to 1⅝ in. in length. The bars were reheat treated by heating in a gas-fired furnace to a temperature between 1500 and 1550 deg F, with soaking time approximately 1 hr, and total heating time from entering to leaving furnace 2 hr 15 min. On leaving the furnace the heated bars required 6 sec to reach the quenching oil. The quenching oil in the 8000-gal capacity tank reached a maximum temperature of 185 deg F, and the bars traveled through 25 ft of oil in 4 min, coming out of the quench with retained heat somewhat above 390 deg F, the capacity of the thermometer for checking the bar temperature at this stage.

Ten of the bar failures were from the base and 2 were from the top. The ground easements eliminated gouging on all except four bars which showed light gouging outside

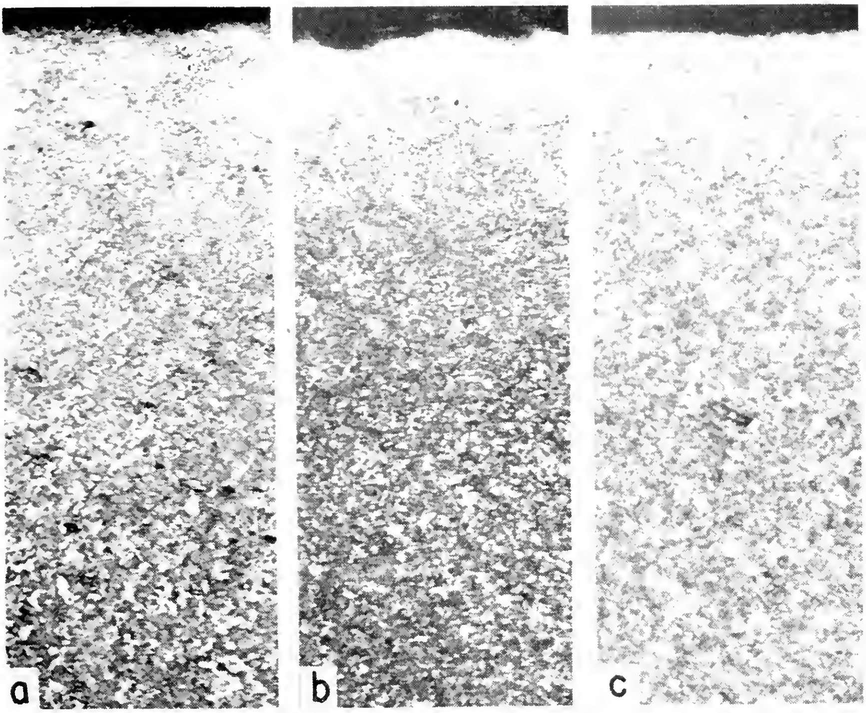


Fig. 3—Micrographs from failed bars.
Magnification about 70×; 2 percent nital etch; a. bar 294S; b. bar 295S; c. bar 298S.

of the easement areas, somewhat below the easements. Nine of the 10 base failures, however, started in rail end gouges; 1 base failure started in an area of heavy bearing 3 in from the rail end and progressed to an oval bolt hole, and 1 crack progressed from a rail end gouge on the base to an oval hole. A fatigue area at this hole 7/8 in. in height was observed. Both top failures started in heavy bearing areas away from the rail ends and progressed to bolt holes.

Magnaflux examination revealed additional transverse cracks on the top surfaces of 10 of the failed bars and 9 of the companion bars. The cracks ranged in length from 1/8 to 1 1/8 in and occurred in heavy bearing areas within a few inches from the center of the bar.

Micrographs taken on specimens from the failed bars revealed a fairly fine grain structure. Typical micrographs are shown in Fig. 4. Depths of decarburization ranged in varying amounts to 0.12 in for these bars.

Lateral deflection readings on the bars indicated that at 100,000 cycles the centers of the bars were bowed outward an average of 0.017 in for the upper flanges and an average of 0.009 in for the lower flanges.

Out-to-out measurements indicated that at 100,000 cycles the lower flanges had moved inward 0.045 in average at the center of bar length and 0.017 in average at the ends of the bars. The upper flanges averaged 0.010 in movement at the center and 0.001 in at the ends.

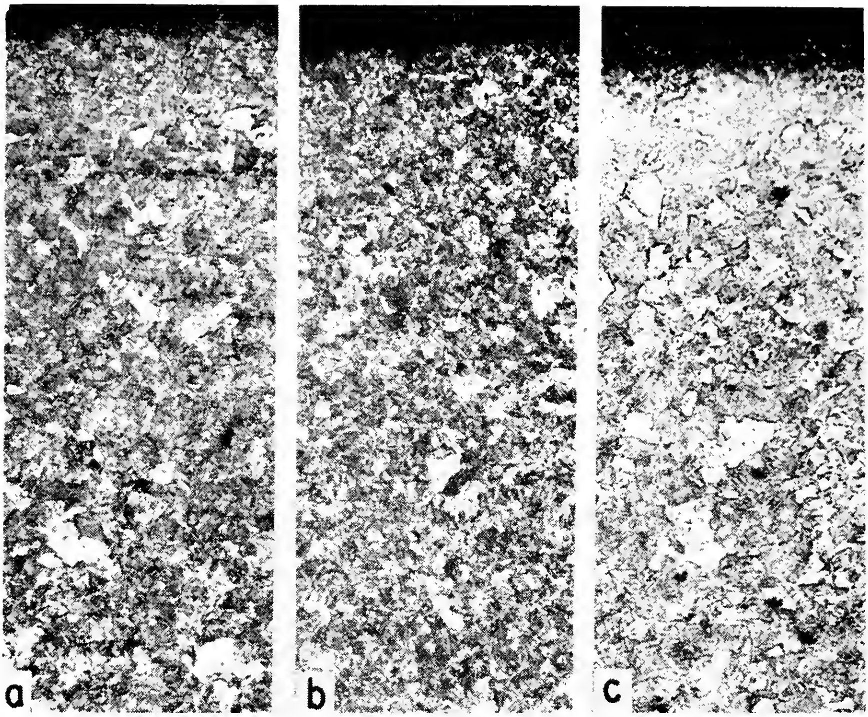


Fig. 4—Micrographs from failed bars.
Magnification about 70×; 2 percent nital etch. a. bar 306N; b. bar 308S; c. bar 314N.

The physical properties of the failed bars, as indicated in Table 2, were above the AREA specifications, except for yield point on 2 bars.

Rolling-Load Tests of Reheat Treated 132 RE Headfree Bars with Ground Easements—Oil Quenched and Tempered

Results of 12 tests of 132 RE headfree used bars, reheat treated after grinding easements, are given in Table 1. These bars (joints 316–327) were oil quenched from 1500 to 1550 deg F and tempered at 800 deg F. The average cycles for failure for these 12 joints is 484,980 cycles.

Six of the bar failures were from the base, 5 were from the top, and 1 bar failed from both the top and base. The ground easements, in general, reduced or eliminated gouging. Exceptions were bars 317S and 318S, on which the easements were ground off center of bar length sufficiently so that gouging was present in the edge of the easement and was severe enough to start a crack. Six other bars showed very light gouging into the shallow edge of the easement or just outside the easement, but not severe enough to start a crack.

Two of the base failures and 1 top failure progressed to bolt holes; however no fatigue areas existed at the holes.

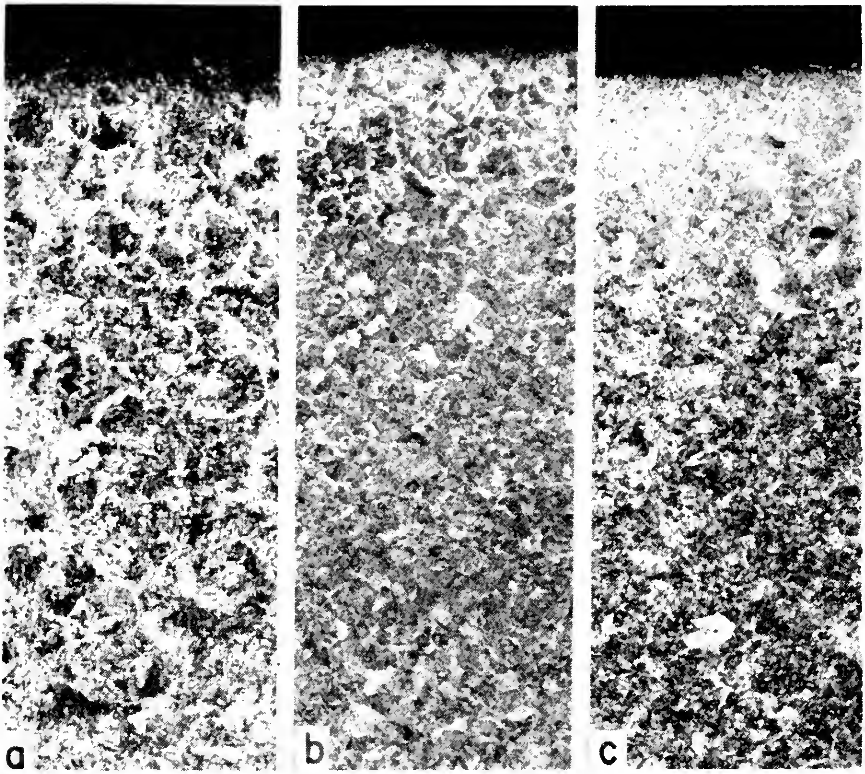


Fig. 5—Micrographs from oil-quenched and tempered bars.
Magnification about 70×; 2 percent nital each. a. bar 316N; b. bar 321N; c. bar 324N.

Magnaflux examination revealed additional transverse cracks on the top surfaces of 5 of the failed bars and 9 of the companion bars. The cracks ranged in length from $\frac{3}{16}$ to 1 in and occurred in heavy bearing areas within a few inches of the center of bar length.

Micrographs taken on specimens from the failed bars revealed, in general, a fairly fine grain structure. Three micrographs are shown in Fig. 5. Depths of decarburization ranged up to 0.015 in for these bars.

Lateral deflection readings on the bars indicated that at 100,000 cycles the centers of the bars were bowed outward an average of 0.005 in for the upper flanges and an average of 0.004 in for the lower flanges.

Out-to-out measurements indicated that at 100,000 cycles the lower flanges had moved inward 0.045 in average at the center of bar length and 0.016 in average at the ends of the bars. The upper flanges averaged 0.010 in movement at the center and 0.001 in at the ends.

The physical properties of these failed bars, as indicated in Table 2, were above AREA specifications, except for yield point on 3 bars.

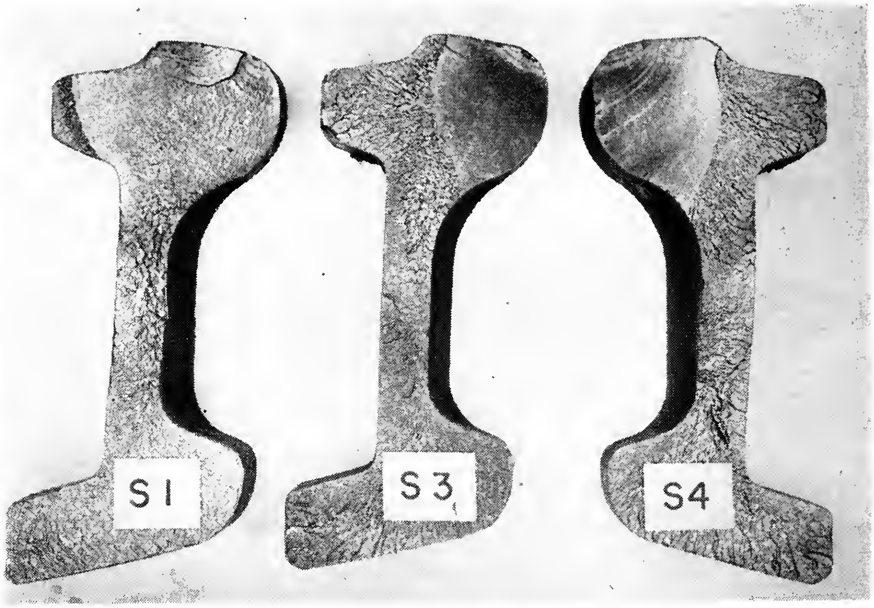


Fig. 6—Service failures of 112 K2 bars.

Failed Bars from Service

Four failed bars from service have been received for examination and testing. These were 112 K2 headfree 36-in bars, rolled in 1944. All of the bars had failed from a crack starting on the top surface at a gouge mark caused by a rail end. Three of the failures are shown in Fig. 6. Brinell hardness measurements were taken on each bar after removing $\frac{1}{16}$ in of surface metal. A tensile specimen was cut from each bar and the data on hardness and physical properties for these bars are listed in Table 3, and plotted against Brinell hardness in Fig. 8, together with data on laboratory tested bars. This plot of Fig. 8 indicates that for a specimen to meet the yield point specification of 70,000 psi it should have a Brinell hardness of 227, and to meet the tensile strength specification of

TABLE 3—BRINELLS AND PHYSICAL PROPERTIES OF FAILED BARS FROM SERVICE

Lab. No.	*Bar Type*	*Year Rolled*	*Hardness Near Top Surface, BHN*	*Hardness on Tensile Specimen, BHN*	*Yield Point, Psi*	*Tensile Strength, Psi*	*Reduction of Area, Percent*	*Elongation 2-In Gage Length, Percent*
S1	112K2 HF	1944	218	179	48,400	92,800	45.6	23.0
S2	112K2 HF	1944	200	163	43,400	87,500	47.0	23.5
S3	112K2 HF	1944	220	181	47,100	92,500	45.0	22.5
S4	112K2 HF	1944	243	192	64,400	109,000	53.2	24.0

AREA specifications: Tensile strength, min 100,000 psi
Yield point, min 70,000 psi
Elongation in 2 in, min 12 percent
Reduction of area, min 25 percent

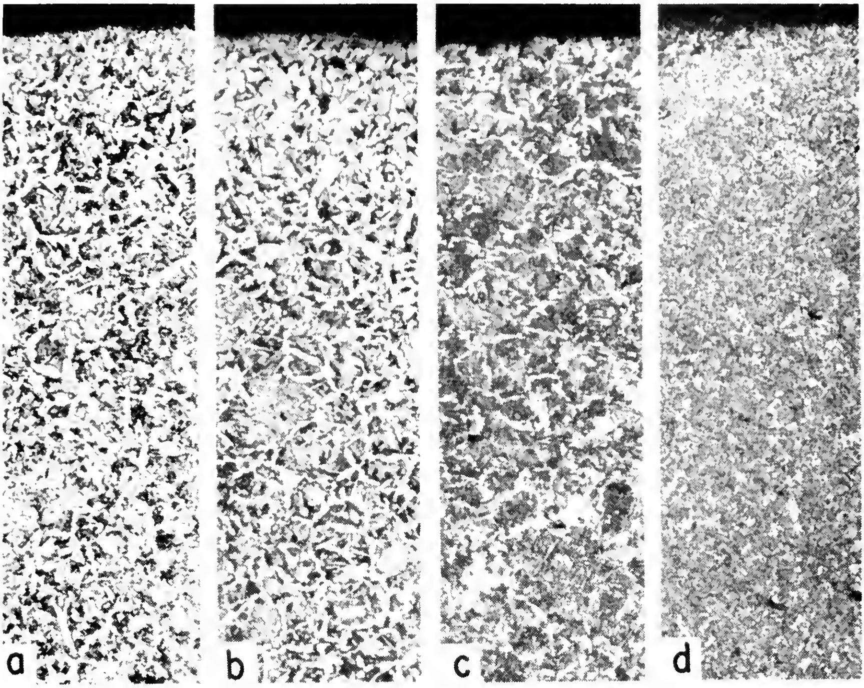


Fig. 7—Micrographs from failed bars from service.
Magnification about 70×; 2 percent nital etch. a. bar S1; b. bar S2; c. bar S3; d. bar S4.

100,000 psi, it should have a Brinell hardness of 198; these are the intersections of the lines through the plotted points with the 70,000 psi and 100,000 psi stress lines.

Brinells on the tensile specimens were considerably lower than those taken near the surface. Micrographs taken on specimens from these bars are shown in Fig. 7. Three of the bars revealed a rather coarse grain structure and also physical properties below the specification. The fourth bar, with higher physical properties, had a finer grain structure. None of the bars passed the yield point specification of 70,000 psi; 1 bar passed the tensile strength requirement of 100,000 psi.

Summary

1. Twelve tests of new 132 RE headfree bars with ground easements averaged 403,610 cycles in the rolling-load tests. Fourteen of the bars failed, 9 from the top and 5 from the base.

2. Twelve tests of used 132 RE headfree bars, reheat treated by oil quenching at 1500 to 1550 deg F, after grinding easements, averaged 761,870 cycles. Two of the failures were from the top and 10 were from the base.

3. Twelve tests of used 132 RE headfree bars, reheat treated by oil quenching at 1500 to 1550 deg F and tempering at 800 deg F after grinding easements, averaged 484,980 cycles. Six failures were from the base, 5 from the top, and 1 from both the top and base.

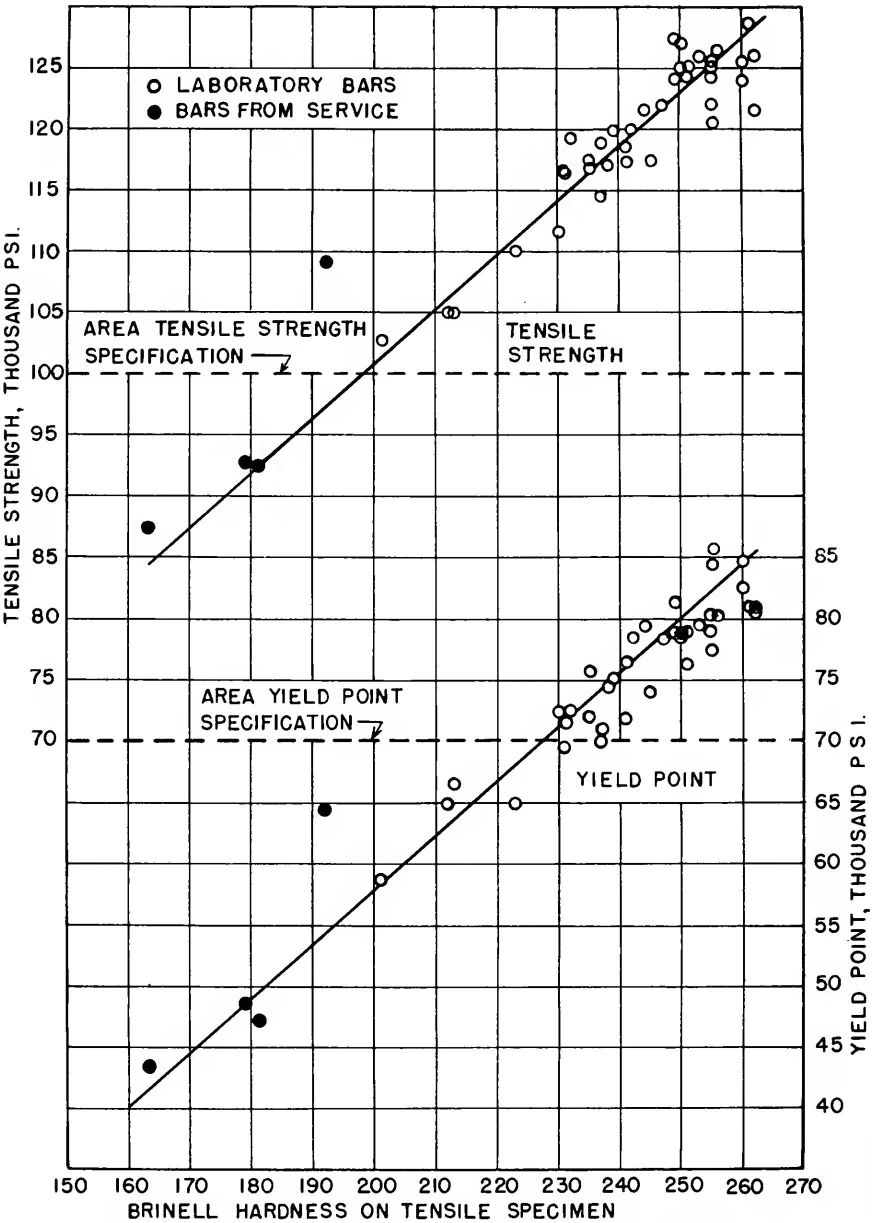


FIG. 8 PHYSICAL PROPERTIES VS. BRINELL OF FAILED JOINT BARS.

4. The ground easements from 1/32 to 7/64 in. in depth were, in general, effective in eliminating or reducing gouging by the rail ends. On properly centered easements no gouging severe enough to start a crack occurred within the easement area.

5. Tests on four 112 K2 headfree bars which failed in service indicated yield points below AREA specifications and Brinell hardnesses below 200 on the tensile specimens. All had failed from a gouge mark on the top surface.

Report on Assignment 8

Causes of Shelly Spots and Head Checks in Rail: Methods for Their Prevention

L. S. Crane (chairman, subcommittee), F. W. Biltz, T. A. Blair, B. Bristow, C. J. Code, W. J. Cruse, J. C. DeJarnette, J. L. Gressitt, C. B. Harveson, S. R. Hursh, K. K. Kessler, C. C. Lathey, W. B. Leaf, E. E. Mayo, Ray McBrian, B. R. Meyers, L. T. Nuckols, R. E. Patterson, J. G. Roney, I. H. Schram, W. D. Simpson, J. S. Wearn, Edward Wise, Jr., J. E. Yewell.

This is a progress report presented as information.

During the past year the investigation has been conducted by three task groups. The work of Group 1 is handled directly by the subcommittee; that of Group 2 by the research staff of the Engineering Division, AAR; and that of Group 3 by the University of Illinois.

The AAR provides funds to support the work conducted by Group 2 and the AAR and AISI, jointly, provide funds to support the work conducted by Group 3.

A small administrative committee comprised of members selected by the AAR subcommittee and the rail manufacturers has met regularly during the past year with the various research investigators for the purpose of reviewing and guiding the conduct of the research work.

The research work conducted to date has failed to reveal any positive solution for this problem. Gage corner contour design improvements made on the 115, 132 and 133 RE sections have assisted in preventing the onset of shelling but have not prevented its eventual occurrence. The results of preliminary investigation conducted by the Engineering Division research staff give some indication that certain maintenance factors may influence the tendency of rails to shell. It is, however, premature to offer any conclusion on this matter until a substantially greater amount of investigative data has been compiled from other railroads and reviewed. The use of heat-treated and chrome-vanadium alloy rail is effective in extending the time until gage corner shelling will occur when the expense of this type of rail may be economically justified.

Group 1

The committee has continued to follow the performance of various installations of heat-treated and alloy-steel rail. In the interest of brevity, only a tabulation of alloy and heat-treated rail installations made since January 1949 is included in this report. It should be observed from the following tabulation that several recent installations of high-silicon rail have been made. Although the results of rolling-load tests at the University of Illinois would indicate that service performance of this rail would not be equal to the service performance heretofore obtained with heat-treated or alloy-steel rail, its cost is

Installations of Alloy and Heat-Treated Rail, Since January 1949

Railroad	Rail Section	Type Rails—Mill	Heat No.	Analysis C	Mn	P	S	Si	Cr	Va	Date Installed	Place Installed	Degree Curvature	Amount of Rails
PRR	155 PS	Heat Treated—Steelton	88507	0.75	0.82	0.011	0.029	0.17	....	....	Jan. 1949	Forge, Pa.	6° Curve	6 rails
			82510	0.76	0.90	0.017	0.035	0.16	....	....				6 rails
C&O	132 RE	Heat Treated—Steelton	87581	0.77	0.83	0.015	0.037	0.15	....	....	May 1949	Martha, W. Va.	3° 6′ curve	8 rails
			82589	0.78	0.79	0.023	0.034	0.17	....	....				4 rails
N&W	132 RE	Heat Treated—Steelton	87581	0.77	0.83	0.015	0.037	0.15	....	....	May 1949	Kermit, W. Va.	6° curve	15 rails
			82589	0.78	0.79	0.023	0.034	0.17	....	....				8 rails
NYC	127 DY	Heat Treated (Lackawanna Rails) (Treated at Steelton)	10440 25435 29436	0.72 0.72 0.71	0.78 0.81 0.85	0.020 0.011 0.014	0.036 0.025 0.031	0.17 0.18 0.19	....	....	July 1950	Cedar Run, Pa.	7° 51′ curve	4 rails
		Alloy—Gary	201457	0.79	1.40	0.013	0.029	0.25	0.95	0.15	July 1950	Cedar Run, Pa.	7° 51′ curve	11 rails
N&W	132 RE	Alloy—Gary	933883	0.74	1.30	....	....	0.25	0.90	0.12	Dec. 1950	Sciota Division	Two 6° curves	1 heat
GN	115 RE	Heat Treated—Steelton	89521	0.76	0.86	0.014	0.037	0.19	....	....	Feb. 1951	Carlton, Minn.	4° Curve	88 rails
DRG&W	133 RE	High Silicon—CF & I	3181	0.79	0.93	0.034	0.033	0.55	....	....	May 1951	Glenwood Canyon	9° 8′ curve	2 heats
			8202	0.77	0.82	0.031	0.027	0.48	....	....		Out of Glenwood Canyon	4° 9′ curve 5° 4′ curve	
PRR	155 PS	High Silicon—Steelton	86594	0.79	0.72	0.010	0.034	0.59	....	....	Oct 1953	Lewiston, Pa.	2° 37′ curve	1 heat
PRR	140 PS	Alloy—Gary	996080	0.69	1.38	0.017	0.022	0.30	1.11	0.13	Oct. 1953	Torrance, Pa.		$\frac{1}{2}$ heat
N&W	140 PS	Alloy—Gary	996080	0.69	1.38	0.017	0.022	0.30	1.11	0.13	Nov. 1953	Sciota Division		$\frac{1}{2}$ heat
DM&IR	115 RE	Alloy—Gary	976186	0.64	1.51	0.018	0.027	0.41	1.11	0.16	Mar. 1954	Proctor Hill, Minn. Two Harbors, Minn. North of Two Harbors		1 heat
GN	115 RE	Heat Treated—Steelton	90005	0.74	0.73	0.02	0.03	0.18	....	....	Apr. 1954	Mesabi Division	7 curves 3° to 7° 36′	166 rails
UP	133 RE	High Silicon—CF & I	2694	0.69	0.84	0.024	0.022	0.57	....	....	Apr. 1954	Wyoming Division	1° curve 3° 7° curve	31 rails 36 rails

INSTALLATIONS OF ALLOY AND HEAT-TREATED RAIL, SINCE JANUARY 1949 (Continued)

Railroad	*Rail Section*	*Type Rails—Mill*	*Heat No.*	*Analysis*							*Date Installed*	*Place Installed*	*Degree Curvature*	*Amount of Rails*
				C	*Mn*	*P*	*S*	*Si*	*Cr*	*Va*				
DRG&W	133 RE	High Silicon—CF & I	13138	0.72	0.93	0.021	0.030	0.65	...	...	May 1951	Kremmling, Colo	4 12° curves	123 rails
AT&SF	132 RE	High Silicon—CF & I	6778	0.78	0.89	0.021	0.025	0.60	...	...		Raton Canyon Colorado Division	9° 52′ curve 10° 24′ curve 9° 0′ curve 10° 0′ curve	1 heat
N&W	132 RE	Heat Treated—Steelton	81033	0.77	0.85	0.01	0.03	0.17	...	...				3 heats
			87062	0.75	0.80	0.01	0.04	0.16	...	...				
			88059	0.75	0.85	0.01	0.03	0.16	...	...				

substantially less than the other types. If it performs as well as anticipated, there are many locations where it might be economically justified where the higher cost of heat-treated or alloy-steel rail could not be justified.

Group 2

The Engineering Division research staff has continued to assist the subcommittee in following the progress of the field tests.

Group 3

The third portion of the assignment is covered by report prepared by Prof. R. E. Cramer, which follows as Appendix 8–a.

Appendix 8–a

Thirteenth Progress Report on Shelly Rail Studies at the University of Illinois

By R. E. Cramer
Research Associate Professor, University of Illinois

Organization and Acknowledgment

The shelly rail studies at this laboratory are financed equally by the Association of American Railroads and the American Iron and Steel Institute. Twelve previous reports have been published annually in the Proceedings of the American Railway Engineering Association. The research program is supervised by a committee composed of engineers from both the AREA Rail committee and the AISI Technical Committee on Rails and Joint Bars.

R. T. Murphy, a student test assistant, has worked on this investigation on a part-time basis this year. Marion Moore, mechanic, has operated the rolling-load machines.

Rolling-Load Test of Heat-Treated Chrome-Vanadium Rail

Previous reports have covered alloy rails and heat-treated carbon-steel rails which gave rolling-load tests from 5 million to 9 million cycles. As a laboratory experiment 1 specimen of a chrome-vanadium alloy rail was oil quenched from 1500 deg F and drawn at 800 deg F for 2 hr. This treatment gave a surface Brinell hardness of 490. This specimen No. 1137–H–1 in Table 1, gave 21,127,000 cycles before a shelling crack developed. It is about 100 Brinell points harder than any previously tested rail and lasted twice as long as any previous rail. The specimen is too hard to machine into specimens for mechanical and fatigue tests.

Rolling-Load Tests of High-Silicon Rails

Five specimens of high-silicon rail were received for tests, which are numbered 1143, 1144, 1146, 1147 and 1148 in Table 1. Two tests are reported on each rail. The number of cycles for failure of the 10 tests range from 1,381,000 to 3,972,000 cycles, with an average of 2,307,200. These tests average more than double the 1 million cycle average which has been obtained in previous tests of standard carbon-steel rails. Pictures of the ten shelling cracks are shown in Figs. 1 and 2.

TABLE 1—PHYSICAL TESTS AND ROLLING-LOAD TESTS, OCTOBER 1, 1953, TO OCTOBER 1, 1954

Specimen Number	*Chemical Analysis*					*Size and Kind of Rail*	*Avg. Brin. Hard.*	*Yield Strength, 0.2 % Psi*	*Tensile Strength, Psi*	*Elong. in 2 In, Percent*	*Red. Area, Percent*	*Charpy Value*		*Endurance Limit, Psi*	*Cycle for Failure, 50,000-Lb Wheel Load*
	C	*Mn*	*Alloys*									*No Notch*	*Key Hole Notch*		
			Si	*Cr-*	*Va*										
1137-H-1	0.74	1.30	0.57	0.90	0.12	132-lb Cr-Va Lab. heat treated	490								21,127,000
1143-A	0.69	0.84	0.57			133-lb high silicon Colorado for UP	266	77,100	137,700	11.8	16.5	124	4.5	61,000	1,441,600
1143-B	0.69	0.84	0.57			133-lb high silicon Colorado for UP	269	77,100	137,700	11.8	16.5	124	4.5	61,000	1,667,100
1144-A	0.69	0.84	0.57			133-lb high silicon Colorado for UP	270	77,100	137,700	11.8	16.5	124	4.5	61,000	1,381,000
1144-B	0.69	0.84	0.57			133-lb high silicon Colorado for UP	270	77,100	137,700	11.8	16.5	124	4.5	61,000	3,972,000
1145-A	0.72	1.38	0.32	1.02	0.15	140-lb Cr-Va	349	111,300	165,700	20.5	21.9	192	3.5	85,000	2,237,900
1145-B	0.72	1.38	0.32	1.02	0.15	Gary for PRR	350								5,014,000
1146-A	0.79	0.72	0.59			155-lb high silicon	281	86,600	148,300	8.3	13.3	103	4.9	65,000	1,409,200
1146-B	0.79	0.72	0.59			Steelton for PRR	281								1,491,000
1147-A	0.78	0.89	0.60			132-lb high silicon	302	83,600	146,000	8.8	14.7	98	4.0	64,250	3,936,000
1147-B						Colorado for AT&SF									3,440,000
1148-A	0.78	0.89	0.60			132-lb high silicon	300	85,500	148,000	9.8	14.5	112	4.3	66,500	2,111,000
1148-B						Colorado for AT&SF									2,225,000

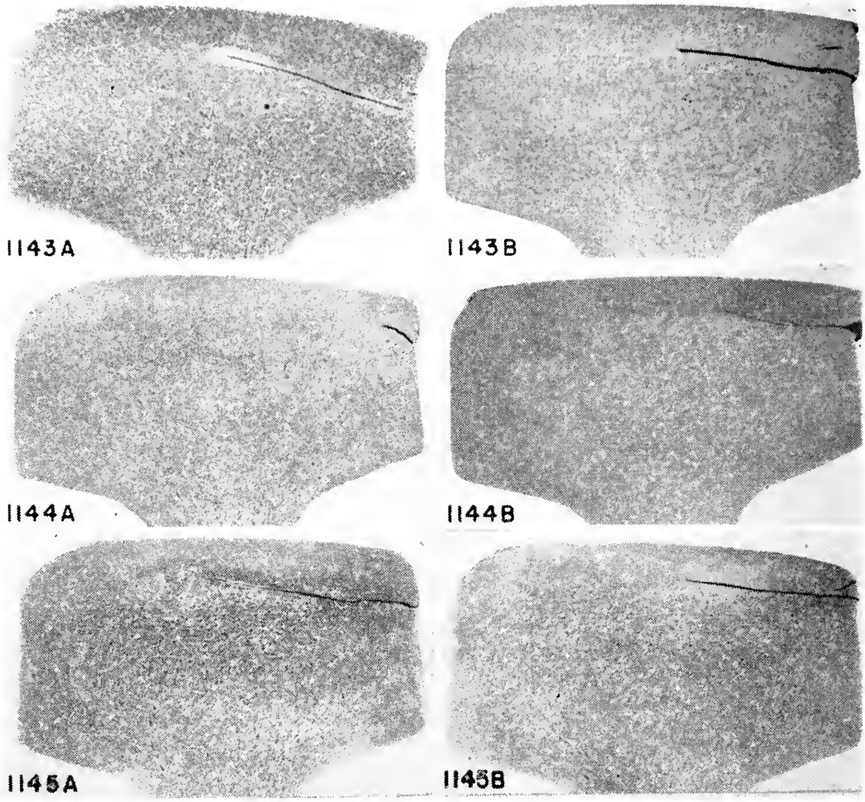


Fig. 1—Shelly failures produced in rolling-load tests.

Specimen Number	*Kind of Specimen*	*Average Brinell Hardness*	*Cycles of 50,000-Lb Wheel Load*
1143A	133-lb high-silicon rail	266	1,441,000
1143B	133-lb high-silicon rail	269	1,667,100
1144A	133-lb high-silicon rail	270	1,381,000
1144B	133-lb high-silicon rail	270	3,972,000
1145A	140-lb chrome-vanadium rail	349	2,237,000
1145B	140-lb chrome-vanadium rail	350	5,014,000

Rolling-Load Tests of 140-lb Chrome-Vanadium Alloy Rail

Specimens from 140-lb chrome-vanadium alloy rail were received for testing from the Pennsylvania Railroad. It is No. 1145 in Table 1. This rail had a Brinell hardness of 350 compared to 365 and 361 for previously tested chrome-vanadium rails, which averaged 7,233,000 cycles for failure. This rail, No. 1145, gave rolling-load tests of 2,237,900 cycles and 5,014,000 cycles, or an average of 3,625,000 cycles, which is considerably below previous tests of chrome-vanadium rails. This may be due partly to the lower Brinell hardness and mechanical properties. Pictures of the shelling cracks of these two specimens are shown in Fig. 1.

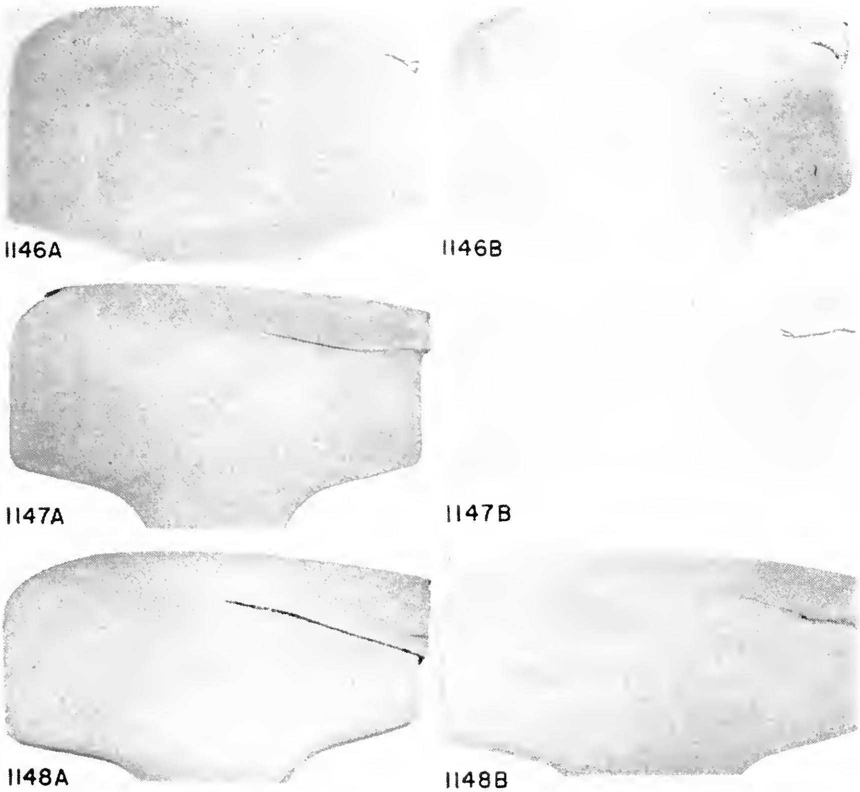


Fig. 2—Shelly failures produced in rolling-load tests.

Specimen Number	*Kind of Specimen*	*Average Brinell Hardness*	*Cycles of 50,000-Lb Wheel Load*
1146A	155-lb high-silicon rail	281	1,409,200
1146B	155-lb high-silicon rail	281	1,491,000
1147A	132-lb high-silicon rail	302	3,936,000
1147B	132-lb high-silicon rail	302	3,440,000
1148A	132-lb high-silicon rail	300	2,110,000
1148B	132-lb high-silicon rail	300	2,225,000

Examination of Shelly Rails from Service

Several detail fractures from shelling were examined in the laboratory for inclusions with the microscope. No unusual inclusions were found in any of these failed rails. One failure is shown in Fig. 3. The lower picture shows most of the shelling crack opened up. There is a longitudinal streak about ½ in from the gage side of the rail, which was the starting point of the internal shelling crack. The top picture shows an etched cross section of the rail with light segregation streaks in the area of the shelling crack. This rail was in service 5 years on a 1-deg curve of the Chesapeake & Ohio Railroad before the failure developed.

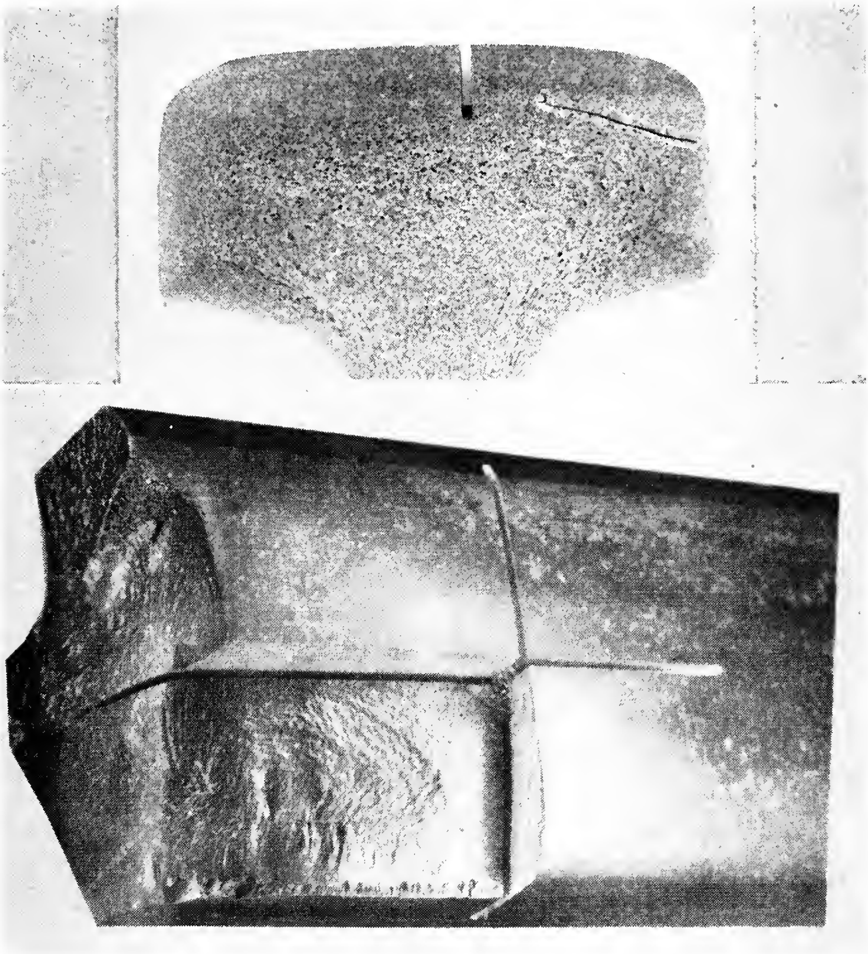


Fig. 3—Shelly rail starting at segregation streak.

Top: Etched cross section, showing light segregation streaks in area of shelling crack. Specimen etched in hot 50 percent hydrochloric acid.

Bottom: Detail fracture from shelling opened up. Note longitudinal streak ½ in from gage side of rail head where shelling crack started.

Rolling-Load Tests to Produce Detail Fractures in the Laboratory

Five rolling-load tests to produce detail fractures from shelling in standard rails were reported last year. The average cycles for failure was 1,652,000. One test of a chrome-vanadium rail failed at 3,225,000 cycles.

This year 1 test on a heat-treated, carbon-steel rail, with Brinell hardness of 361, failed at 4,514,600 cycles from a detail fracture starting at the bottom corner of the rail head. No shelling crack developed. A second specimen of heat-treated, carbon-steel rail, with Brinell hardness of 383, ran 9,754,000 cycles without developing a shelling failure or detailed fracture. The test had to be stopped because a long crack had developed in the rail web.

These tests indicate that both chrome-vanadium alloy rails and heat-treated, carbon-steel rails give better resistance to the production of detail fractures than straight carbon-steel rails. A series of rolling-load tests to produce detail fractures in high-silicon rails has been started and will be continued next year.

Summary

1. One specimen of a chromium-vanadium rail, heat treated to 490 Brinell hardness, gave a rolling-load test of 21 million cycles.

2. Ten specimens of high-silicon rails gave rolling-load tests that averaged 2,307,000 cycles.

3. Two specimens of 140-lb chrome-vanadium alloy rail, gave rolling-load tests that averaged 3,625,000 cycles.

4. Examination of shelly rails from service did not reveal unusual inclusions in the steel. Photographs of one shelling crack indicate that it started at a segregation streak in the rail.

5. Rolling-load tests to produce detail fractures from shelling indicate that both chrome-vanadium alloy rails and heat-treated carbon-steel rails resist the production of detail fractures better than standard carbon-steel rails.

6. All rolling-load tests to produce shelling indicate that rails with higher hardness, with corresponding increase in mechanical strength, give longer laboratory rolling-load tests.

Report on Assignment 9

Recent Developments Affecting Rail Section

W. J. Cruse (chairman, subcommittee), E. L. Anderson, F. W. Biltz, T. A. Blair, C. B. Bronson, W. J. Burton, C. J. Code, L. S. Crane, P. O. Ferris, C. J. Geyer, S. R. Hursh, K. K. Kessler, L. R. Lamport, C. C. Lathey, Ray McBrian, B. R. Meyers, W. G. Powrie, R. B. Rhode, J. C. Ryan, G. L. Smith, H. F. Whitmore, R. P. Winton, Edward Wise, Jr.

This is a progress report, presented as information.

The topics being pursued under this assignment are:

(a) Redesign of 100 RE rail and joint bars.

(b) Study of rail web bolt hole finish in regard to fatigue failure.

(c) Study of the proposal for the adoption as an AREA standard of a headfree joint bar for the 140 RE rail section.

(a) The study of the redesign of 100 RE rail and joint bars was carried out at the Central Research Laboratory by Kurt Kannowski, metallurgical engineer, and other members of the Engineering Division research staff of the Association of American Railroads, under the direction of G. M. Magee, director engineering research. The first trial redesign of the 100-lb section was completed and a test specimen machined from a 175-lb crane runway section has been subjected to strain gage tests, the results of which do not quite measure up to expectations. Further work on this assignment will be held in abeyance owing to waning interest, and this committee will make some further study of the need for a redesign of this section, including a canvass of the users.

(b) The report of the Engineering Division research staff, presented herewith as Appendix 9–a, covers the study of rail web bolt hole finish in regard to fatigue failure.

(c) On recommendation from the committee, Mr. Magee designed a 140-lb headfree joint bar for use as an alternate for railroads desiring a headfree bar in preference to the head-contact bar. A survey of the proposal for the adoption of this headfree bar as an AREA standard is now in progress.

Appendix 9–a

The Effect of Stress Raisers Around a Bolt Hole on the Fatigue Life of a Rail

The failures within the joint bar limits of a rail are by far the largest of any type of failure reported in the annual rail failure statistics. This fact warrants the attention and effort being given to eliminate this type of failure. In the last rail failure statistics report, these failures amounted to 36 percent of all of the failures reported. By means of changing design and limiting corrosion, considerable progress has been made in decreasing these failures during the last six years. The Committee on Rail has initiated this study to investigate the effect of the various stress raisers around the bolt hole of a rail in order to reduce these failures still further. The stress raisers which have caused the failures originating at the bolt hole are inherent in the rail production process. It is the purpose of this study not only to evaluate the effect of these stress raisers, but also to suggest a practical correction of the defects.

The study of the effect of stress raisers at the bolt hole of a rail, using a fatigue testing machine, has been carried on at the AAR Research Center by Kurt Kannowski, metallurgical engineer, and Joseph Borrino, laboratory assistant, under the direction of G. M. Magee, director of engineering research of the Association of American Railroads.

A universal fatigue testing machine, as shown in Fig. 1, was obtained, and a bending fixture, as shown in Fig. 2, was designed. The function of the machine is to apply a vertical vibratory force to any specimen or structure attached between the heavy stationary frame and the top platform of the oscillator assembly. This alternating force can be adjusted to apply to bending specimen, such as was used in this test, any combination of tensile or compressive stress within the capacity of the machine. The alternating force is applied 1800 times a minute to an elastic test specimen, and can be adjusted between zero and 5000 lb. It is accurate within 2 percent or 20 lb, whichever is greater. The maximum allowable movement of the oscillating assembly is ± ¼ in amplitude at zero preload, and ± ⅛ in amplitude at full preload.

Due to the limited capacity of the equipment of this type, it was impossible to produce the same stress and stress range in the rail specimen with the bolt hole as would be produced in track. However, it was possible to produce a magnitude and range of stress that would effectively evaluate the effect of bolt hole finish on fatigue strength.

In designing the bending fixture, it became necessary to suspend the specimen so that the flexure took place through the thin section of the web, as shown in Figs. 2 and 4. To eliminate as many variables as possible, rails as rolled, drilled and inspected by the producers, were used. These rails were submitted for testing by the New York Central, Louisville & Nashville, Pennsylvania, and Southern Railroads. The test specimens were selected by the railroad personnel to represent stress raisers, such as gouges due to improperly ground drills, and burrs.

The test specimens, as shown on Fig. 7, were machined to have 1 in of solid metal on either side of the bolt hole. The specimen is bolted firmly in the bending fixture, as shown on Figs. 2 and 4. The line sketch on Fig. 3 illustrates the function of the bending fixture. Test specimen A becomes part of beam E A F, which is suspended on the flexible supports D and D_1, with pivot points E and F. The top of the oscillator B provides the bending force, which is applied at points G and H. A dimensioned detailed drawing of the bending fixture is presented on Fig. 4. The method of securing the test specimen to the fixture, and the flexplates by which the specimen is bent, are shown in detail, as well as the platten which supplies the alternating force.

The force used is the dynamic load exerted upward and downward on the specimen. The specimen was tested in completely reversed flexure so that the stress on each surface varied from a maximum compression to a maximum tension in what would be a vertical direction in the rail web in track. In selecting the loads and rail sections for this investigation a series of preliminary tests was performed to determine the loads, which were applied as shown on Tables 1 and 2. During this investigation strain gages were placed at each edge of the bolt hole and at the edge of the specimen, at positions designated 1 and 2, respectively, shown in Fig. 5. Tests were run with different applied loads from the testing machine, and the stresses determined at these two locations are shown in Fig. 5 for 132-lb rail. It will be noted, as would be expected, that the stress at the edge of the bolt hole was considerably in excess of that at the edge of the specimen, due to the stress concentration effect of the bolt hole. Considerable difficulty was experienced with obtaining strain gage measurements because the gages would usually go out of operation at the high reversal speed of the machine before an opportunity was offered to measure the stress. Checks were conducted for some time, which proved satisfactorily that the applied load in the testing machine could be depended upon for accuracy, and that it remained constant throughout. Accordingly, the indicated load on the machine for making the comparisons was used and the stress measurements were discontinued.

Using the relationship between stress in bolt hole and applied load as shown in Fig. 5 and the data in Table 1 for the test group of bolt holes containing no deformations, the relationship between reversed flexural stress and cycles for failure has been shown in Fig. 6 with the solid triangles. As a matter of interest there is also shown on this diagram the data obtained in fatigue tests at the University of Illinois on specimens cut from the rail web with as-rolled surfaces under completely reversed flexural stress, as shown in AREA Proceedings, Vol. 48, 1947, page 808. It will be noted that the agreement between these two series of tests is remarkably good, the indication being that the fatigue strength for the bolt hole specimens is somewhat lower, which is probably due to the fact that it was impossible to get the strain gage directly at the edge of the hole.

The 132-lb RE section was used because it represents the heaviest of AREA sections, and the 140-lb PS section was used because it had a bolt hole location in the heavier web area. To establish a basis for comparison, test specimens of both sections which had no burrs, brands or gouges were subjected at the standard loadings to the repeated flexure test in order to produce a fatigue failure. A specimen of this type is shown on Fig. 8.

The severity of the defects varied from light to heavy drill gouges, and from light to heavy burrs, as well as the location of the brand on the edge of the hole. This last condition is caused by drilling through the brand, which is the producers identification in raised letters and figures. The combination of these various defects had a considerable effect on the results, as shown in Tables 1 and 2. Fig. 13 is an extreme example of an improperly drilled hole, showing a combination of these various defects.

The segregations which occur frequently in rail steel affected the results to the extent that data of failures with segregations had to be discarded. A typical example of a specimen that failed due to a segregation is shown on Fig. 15. In connection with this condition a metallurgical examination was made of the specimen which showed unexpectedly early failures and of specimen which had a long fatigue life. In every case the structure and cleanliness of the steel were normal. The failures, excepting those due to the segregations, were produced by the deformations.

A condition which shortens the fatigue life more than any other combination of defects is shown on Fig. 16, illustrating a fatigue failure due to a brand and a burr. The type of fracture caused by the various defects is shown on Fig. 14, which consists of sections cut from the fractured test specimen showing the defect, the start of the fracture, and part of the bolt hole. It may be noted that the failure started at the edge of the clean hole, that the burr caused the failure of specimen 18B, and that the burr and the brand had a combined effect on the failure of specimen 19B. On specimen 24B the failure started at the burr and progressed to the gouge mark, which caused the final break due to its notch effect. It is of interest to note that the reamed hole shown by specimen 40F has a failure from the edge of the hole very similar to that of the clean or standard drilled hole.

The data on Tables 1 and 2 were obtained by means of the previously described test specimen of the 132-lb RE and 140-lb PS rail sections. These test specimens had 1 in of solid metal each side of the bolt hole. In machining the outside faces of the specimen the dimensions were held to ± 0.003 in. A closer tolerance could not be maintained because of the drilled finish on the side of the bolt hole. The number of cycles to failure are considered critical in this investigation. If a specimen did not break after 10,000,000 cycles the test was discontinued.

It is of interest to note in Table 1 that the drill gouges had the least effect on the results. A considerable reduction in the fatigue life can be noted at all loadings. The variation of the results is due to the difference in depth and number of drill gouges. The results of the bolt hole with no deformation checked very closely. The effect of the burr again shows a further reduction in the fatigue life. There again the size of the burr caused the variation in number of cycles to failure. If a bolt hole was drilled through the brand, it may be noted in the next group that the fatigue life was lowered even further. There again the exact location of the brand on the edge of the bolt hole caused the difference in the results, as may be noted in the 1250-lb loading which has a range of cycles to failure of 805,000 to 479,000. The combination of a bolt hole with a burr, drilled through the brand, reduced the fatigue life further than any of the defects in this investigation taken singly. Specimens with the burrs and brands, or a combination of the two, broke relatively early during the test so that the effect of drill gouges which were present could not be determined. In Table 2, which consists of data obtained on the 140 PS specimen, the investigation was limited somewhat by the pronounced lack of difference in the type of deformation, as well as the difference in the location of the bolt hole in reference to the center of the web. The section was also much heavier than that of the 132-lb RE section. All of the specimens had a defect of some type. The least effective defect, that of fine drill gouges, was considered as a standard. The balance of the data in this case permits us to show the effect of the combination of drill gouges and burrs, which caused a failure very early in the fatigue life of the specimen. Due to the fact that very few holes were drilled through the brand, no extensive investigation of this defect could be made. It must be noted that the few specimens which had a hole drilled through the brand showed a decidedly shorter fatigue life in their groups.

Several methods of eliminating the effects of these deformations were investigated. To eliminate the gouges which have the least effect on the fatigue life, several specimens were reamed. They showed a slight improvement over the standard drilled holes and holes with drill gouges. A flat chamfer at an angle of 59 deg, removing the edge of the hole, as shown on Fig. 9, was tried. In Table 1 no improvement can be noted over the standard hole, but in the case of the burrs and brands a great improvement was made in the fatigue life. This can also be noted in Table 2. A chamfer with a slight radius, as shown on Fig. 10, extended the fatigue life even further in comparison with the burrs and brands in Tables 1 and 2. It must be noted that this chamfer had the effect of extending the fatigue life of the 140-lb PS section. The loading was increased by 250 lb and still showed results comparable to results in the other groups at 1750-lb loads. This chamfer was machined with a tool as shown on Fig. 18.

A tool, as shown on Fig. 15, was used in peening the edge of the bolt hole to produce a finish, as shown on Fig. 11. This procedure was very effective in the case of burrs, but had very little effect if the hole was drilled through the brand. The effect of this operation can be noted both in Tables 1 and 2. In both cases the loads were increased by 250 lb to produce results comparable to those at lower loads on groups with or without defects. Shot peening of the bolt hole was investigated, as shown on Figs. 12 and 7. As can be noted in Tables 1 and 2, this method proved the most effective. In none of the six specimens tested at increased loads did the failure start at the edge of the hole. It must be noted that the increase of the fatigue life in this group exceeded that of all other groups.

Results obtained in this investigation have definitely indicated that the effect of the stress raisers on the fatigue life of the rail sections is very pronounced. All these stress raisers around the bolt hole were produced in the manufacturing process. The statistical data in Tables 1 and 2 definitely indicates that a bolt hole drilled with a dull or improperly sharpened drill through a brand reduces the fatigue life of the rail by 50 percent. Closer control of the manufacturing process would eliminate a considerable number of detected and service failures in track. As can be noted from the last half of this investigation there are several methods of correcting even the slightest defects. The machining and cutting operations, such as reaming and chamfering, may not be easily adaptable to the manufacturing methods or field operations by the railroads, even though the French railroads claim great success in combating bolt hole failures by reaming. Peening by means of a tool such as shown on Fig. 17 appears to be by far the most practical method in that this tool can be adapted to use in any portable air or electric power tool. The shot peening, which showed best results in extending the fatigue life, requires a type of equipment which would not lend itself to adaptation to the rail production methods or to field operation by railroads. Consideration should be given to this method in salvage yard operation or in track equipment production.

TABLE 1—EFFECT OF STRESS-RAISERS ON BOLT HOLE OF RAIL. RESULTS ON SONNTAG FATIGUE TESTING MACHINE USING 132 RE RAIL

Spec. No.	*Supplied by Railroad*	*Bolt Hole Appearance*	*No. Cycles to Failure*	*Load Lb*	*Remarks*
2A	L&N	No deformation	12,400,000	1000	Did not break
24A	Southern	"	11,120,000	1000	"
39A	NYC	"	10,574,000	1000	"
23A	Southern	"	1,313,000	1250	Breaks from corners
4A	L&N	"	1,303,000	1250	"
38C	NYC	"	590,000	1500	"
4B	L&N	"	395,000	1500	"
23B	Southern	Drill gouges	4,279,000	1000	Break from surface of hole
24B*	Southern	"	1,974,000	1000	"
9C	L&N	"	3,328,000	1000	"
8A	L&N	"	1,180,000	1250	"
9B	L&N	"	925,000	1250	"
5C	L&N	"	256,000	1500	"
36A	L&N	"	321,000	1500	"
18B	Southern	Burr	3,064,000	1000	Break from burr
8B	L&N	"	2,564,000	1000	"
18A	Southern	"	2,084,000	1000	"
9A	L&N	"	891,000	1250	"
20B	Southern	"	807,000	1250	"
25A	Southern	"	688,000	1250	"
18C	Southern	"	519,000	1250	"
19C	Southern	"	295,000	1500	"
4C	L&N	"	236,000	1500	"
7B	L&N	Brand	1,565,000	1000	Break thru brand
6C	L&N	"	1,533,000	1000	"
6A	L&N	"	805,000	1250	"
7A	L&N	"	479,000	1250	"
38A	NYC	"	502,000	1500	"
20A	Southern	"	495,000	1500	"
6B	L&N	"	334,000	1500	"
8C	L&N	Burr and brand	1,480,000	1000	Break from burr and brand
3A	L&N	"	1,971,000	1000	"
19B	Southern	"	785,000	1250	"
1B	L&N	"	760,000	1250	"
1C	L&N	"	345,000	1500	"
7C	L&N	"	236,000	1500	"
17A	L&N	Drill chamfer, 59°	12,340,000	1000	Did not break
40A**	NYC	"	2,397,000	1000	Break on web near chamfer
25C	Southern	"	1,375,000	1250	"
5A	L&N	"	970,000	1250	"
5B	L&N	"	847,000	1250	"
17B	L&N	"	388,000	1500	"
17C	L&N	"	351,000	1500	"
9D	L&N	Radius chamfer	12,914,000	1000	Did not break
37B	NYC	"	12,925,000	1250	"
23C	Southern	"	2,822,000	1250	Break on web near chamfer
39C†	NYC	"	1,592,000	1250	"
36B***	L&N	"	1,346,000	1250	Break from brand
24C	Southern	Rad. cham.+drill gouges	1,380,000	1250	Break on web near chamfer
22B	Southern	" +undercut	1,234,000	1250	Break from under cut
35A	L&N	" +brand	738,000	1250	Break from brand
37E	NYC	Radius chamfer	824,000	1500	Break on web near chamfer
9E	L&N	"	509,000	1500	"
9F	L&N	"	539,000	1500	"
40D	NYC	Reamed hole	12,740,000	1000	Did not break
6E	L&N	"	2,805,000	1250	Break from corner
6F	L&N	"	1,958,000	1250	"
40E	NYC	"	1,553,000	1250	"
40F	NYC	"	895,000	1500	"
6D	L&N	"	572,000	1500	"
35C	L&N	Peened cor.+brand	1,201,000	1000	Break thru brand
40B	NYC	Peened corners	15,545,000	1250	Did not break
22C	Southern	"	12,847,000	1250	"
37C	NYC	"	956,000	1500	Break on web near corner
37D	NYC	"	726,000	1500	Break from corner
22A†	Southern	"	657,000	1500	Break on web near corner
36C†	L&N	"	279,000	1500	"
35B	L&N	Peened lightly	388,000	1500	Break from corner
37F	NYC	Peened corners	365,000	1750	"
37A	NYC	"	319,000	1750	Break on web near corner
2G	L&N	Shot-peened hole	15,052,000	1250	Did not break
2D	L&N	"	1,221,000	1500	Break from web
25D	Southern	"	597,000	1750	"

†Segregation in web.
*Fatigue life affected by small burrs.
**Large gouges aided failure.
***Small brand mark at outer edge of specimen.

TABLE 2—EFFECT OF STRESS-RAISERS ON BOLT HOLE OF RAIL. RESULTS ON SONNTAG FATIGUE TESTING MACHINE 140 PS RAIL

Spec. No.	*Supplied by Railroad*	*Bolt Hole Appearance*	*No. Cycles to Failure*	*Load Lb*	*Remarks*
12A	Penn	No burr, fine drill gouges	2,582,000	1250	Breaks from corners
32B*	Penn	"	2,540,000	1250	"
32C	Penn	"	2,117,000	1250	"
10A	Penn	"	1,281,000	1500	"
32A*	Penn	"	763,000	1750	"
29B	Penn	"	515,000	1750	"
15A	Penn	No burr, avg. drill gouges	4,451,000	1000	Break from corners and surface of hole
29C	Penn	"	1,849,000	1250	"
10B	Penn	"	1,678,000	1250	"
14A	Penn	"	1,196,000	1500	"
31A	Penn	"	1,164,000	1500	"
31B	Penn	"	582,000	1750	"
29A	Penn	No burr, large drill gouges	751,000	1500	Breaks from corners and surface of hole
15B	Penn	"	725,000	1500	"
15C	Penn	"	605,000	1500	"
14B	Penn	Slight burr, fine drill gouges	2,255,000	1125	Break from burr, corners, and surface of hole
12B	Penn	"	1,186,000	1500	"
28B	Penn	"	1,124,000	1500	"
27B**	Penn	"	932,000	1500	"
31C	Penn	"	787,000	1500	"
10C	Penn	"	532,000	1750	"
28A	Penn	Slight burr, large drill gouges	1,796,000	1250	Breaks from burr, corners, and surface of hole
27A**	Penn	"	1,556,000	1250	"
13B	Penn	"	898,000	1500	"
11B	Penn	"	443,000	1750	"
33C	Penn	Burr, fine drill gouges	2,291,000	1250	Breaks from burrs
11C	Penn	"	2,164,000	1250	"
33B	Penn	"	923,000	1500	"
27C	Penn	"	494,000	1750	"
14C	Penn	Burr, average drill gouges	1,609,000	1250	Break from burrs and surfaces of hole
11A	Penn	"	1,029,000	1500	"
13C	Penn	"	523,000	1750	"
28C	Penn	"	418,000	1750	"
26A	Penn	Chamfer, 59°	12,271,000	1250	Did not break
16A	Penn	"	10,341,000	1250	"
26B	Penn	"	1,751,000	1500	Breaks from web adjacent to chamfer
16B	Penn	"	1,409,000	1500	"
26C	Penn	"	956,000	1750	"
16C	Penn	"	661,000	1750	"
30A	Penn	Radius chamfer	15,229,000	1500	Did not break
30B	Penn	"	10,045,000	1500	"
49A*	Penn	"	3,520,000	1500	Breaks from corner & brand
30C	Penn	"	1,330,000	1750	Breaks from web adjacent to chamfer
49B	Penn	"	1,124,000	1750	"
48C	Penn	"	738,000	1750	"
48A	Penn	"	616,000	2000	"
48B	Penn	"	566,000	2000	"
49C	Penn	"	520,000	2000	"
33A	Penn	Peened corners	10,312,000	1250	Did not break
48E	Penn	"	10,276,000	1500	"
49D	Penn	"	3,592,000	1500	Breaks from web adjacent to chamfer
49E	Penn	"	2,246,000	1500	"
48F	Penn	"	732,000	1750	"
48G	Penn	"	468,000	2000	"
48D	Penn	Shot-peened hole	15,422,000	1500	Did not break
49F	Penn	"	11,035,000	1750	"
49G	Penn	"	1,491,000	2000	Breaks from web

*Specimen with brand.
**Specimen showed one crack beginning at brand.

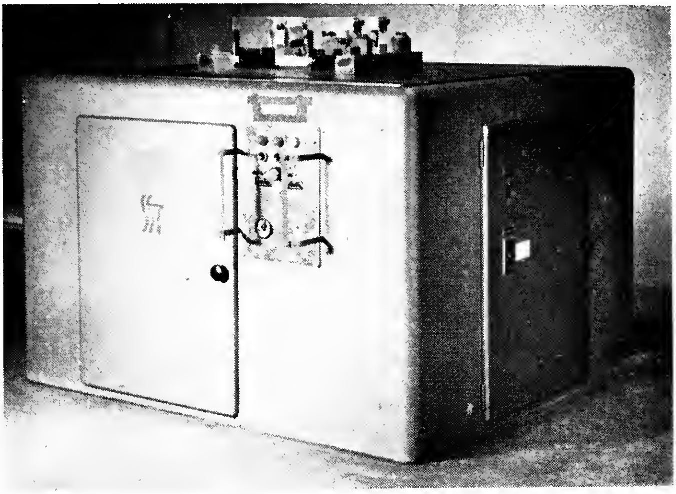


Fig. 1—Sonntag universal fatigue testing machine.

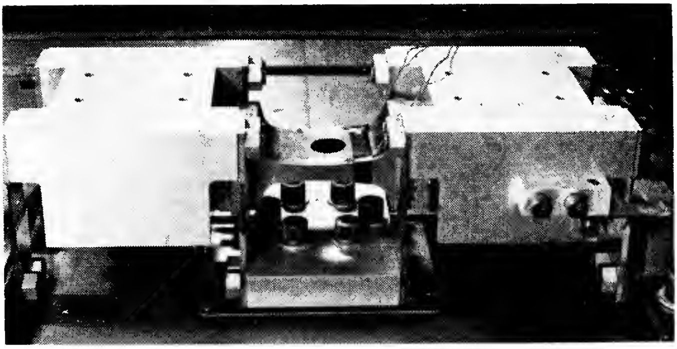


Fig. 2—Fatigue bending fixture with rail specimen in position.

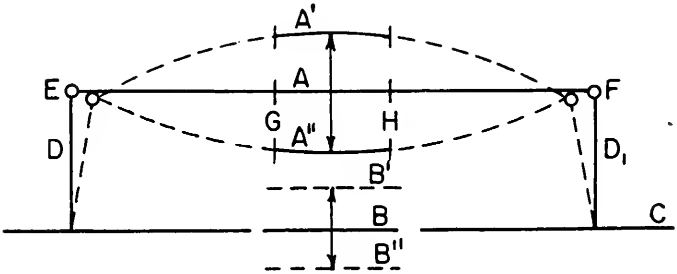


Fig. 3—Schematic diagram of fatigue bending fixture.

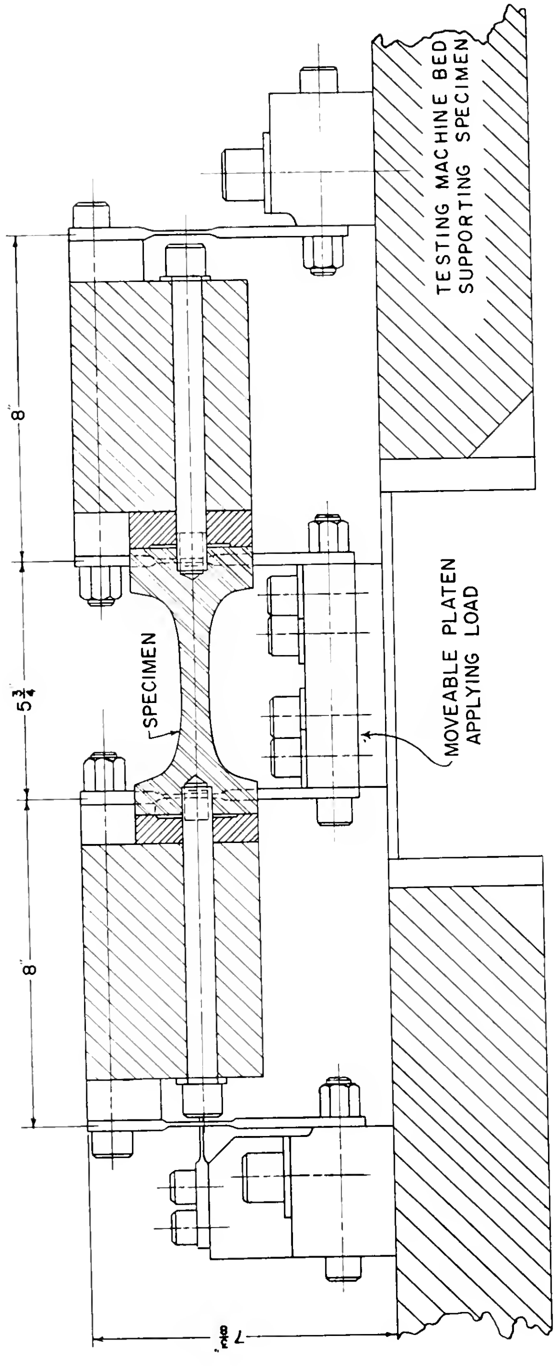


Fig. 4—Detail of fatigue bending fixture.

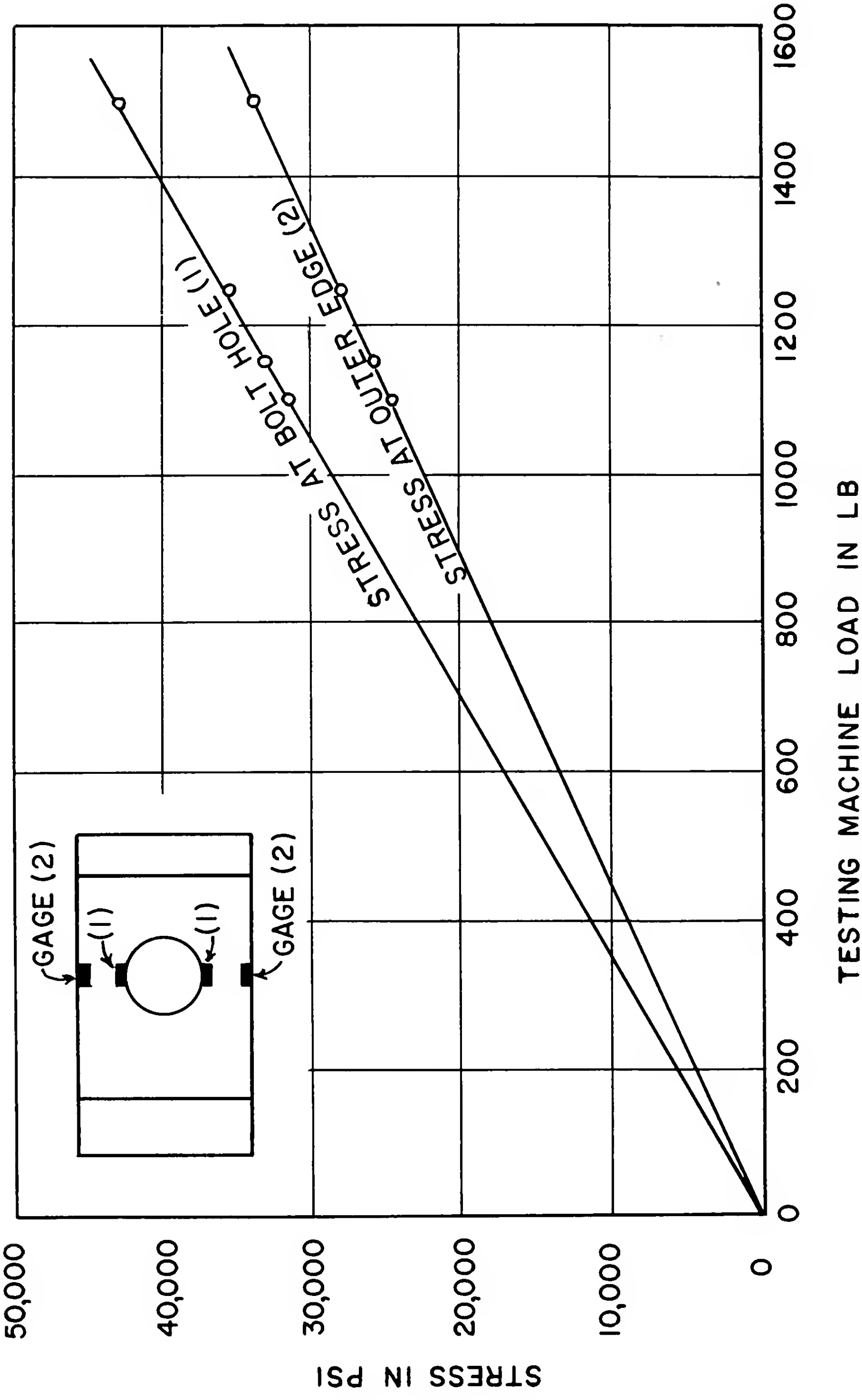
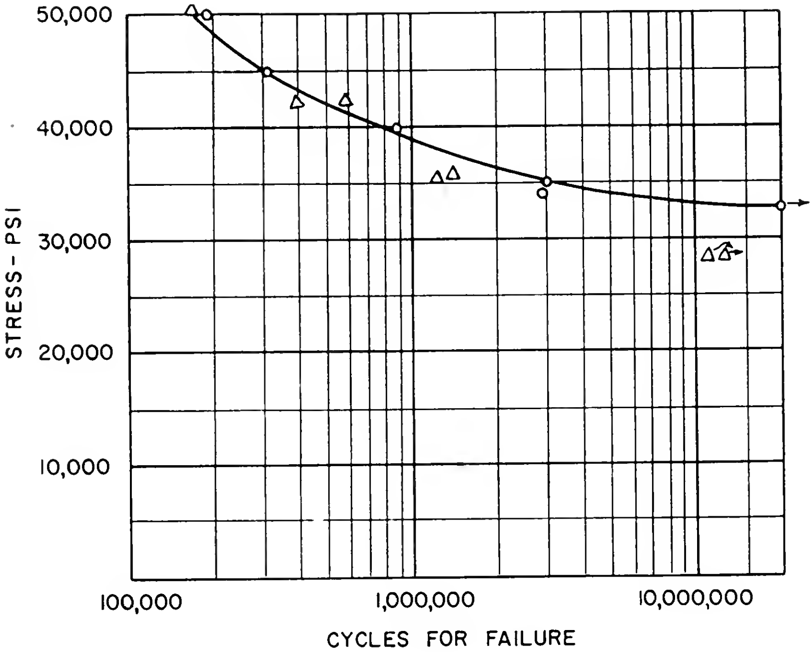


Fig. 5—Relation between testing machine load and measured stress on specimen—132 RE rail.



NOTES:

o LABORATORY FATIGUE TEST AT U. OF I. ON SPECIMENS WITH AS ROLLED SURFACES UNDER COMPLETELY REVERSED FLEXURAL STRESS.

Δ BOLT HOLE SPECIMEN TESTS AT THE RESEARCH CENTER — 132-RE RAIL UNDER COMPLETELY REVERSED FLEXURAL STRESS.

Fig. 6—S–N diagram, bolt hole tests.

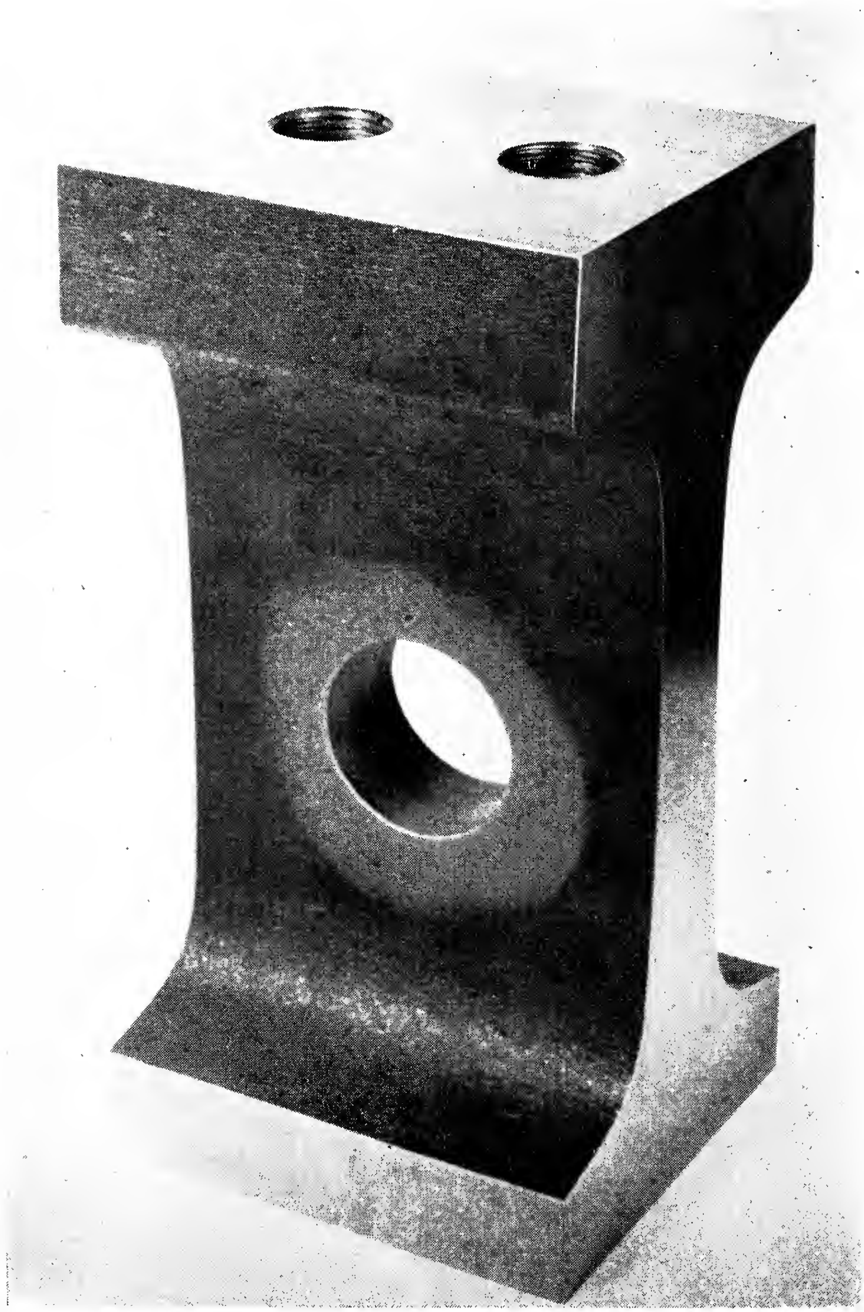


Fig. 7—Rail section machined to dimensions for fatigue testing.

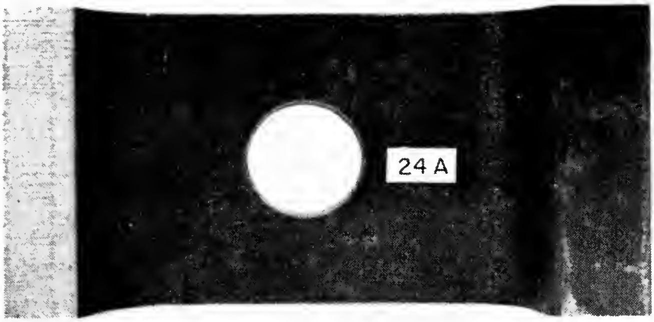


Fig. 8—Standard specimen.

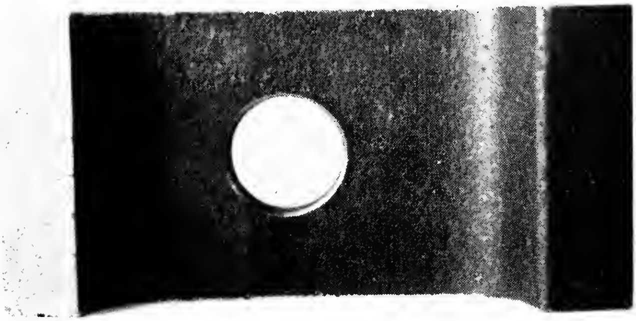


Fig. 9—Specimen with angled chamfer.

Fig. 10—Specimen with radius chamfer.

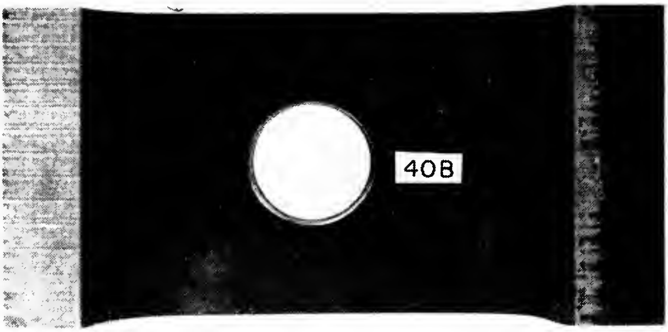


Fig. 11—Specimen with peened hole.

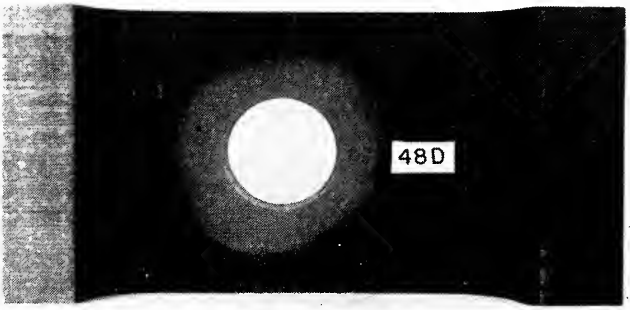


Fig. 12—Specimen with shot-peened hole.

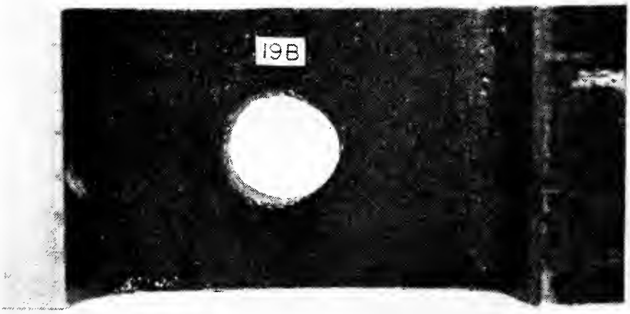


Fig. 13—Specimen with badly drilled hole.

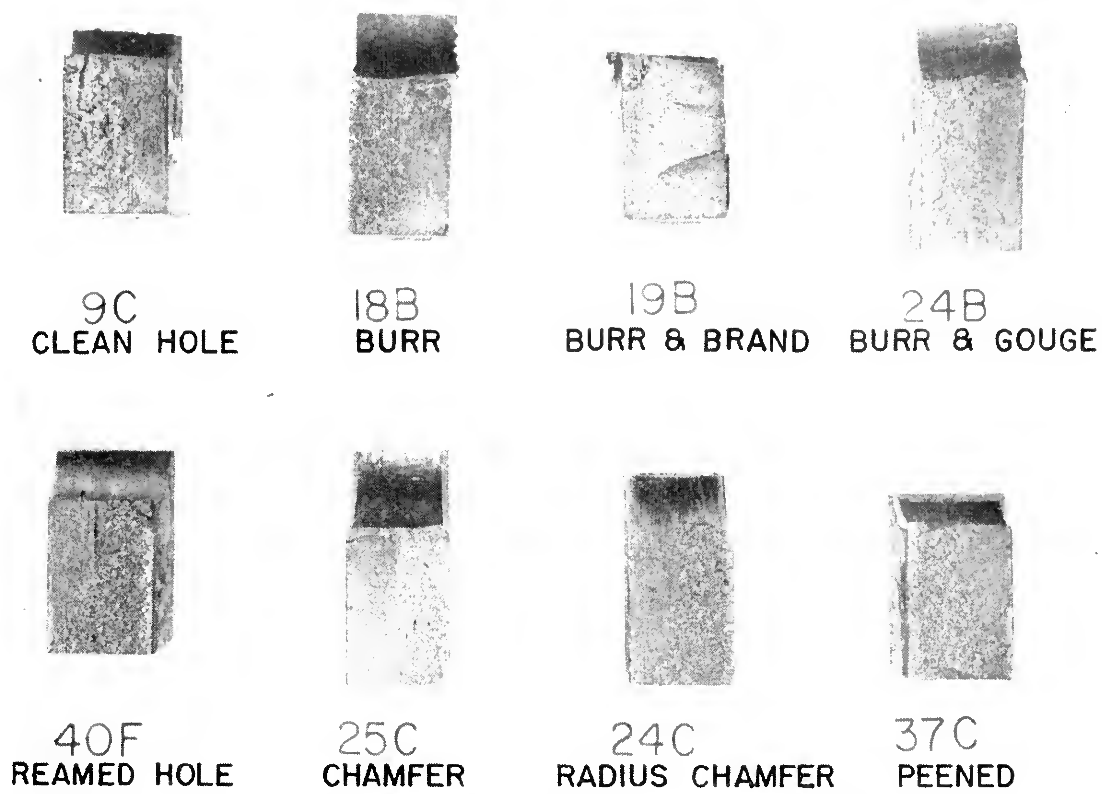


Fig. 14—Typical fatigue failures produced with Sonntag universal fatigue testing machine.

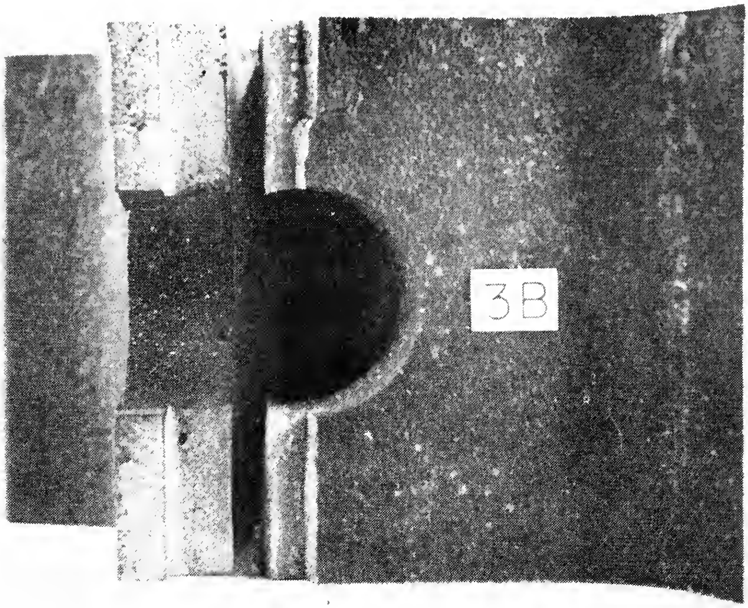


Fig. 15—Type of failure caused by segregation in web.

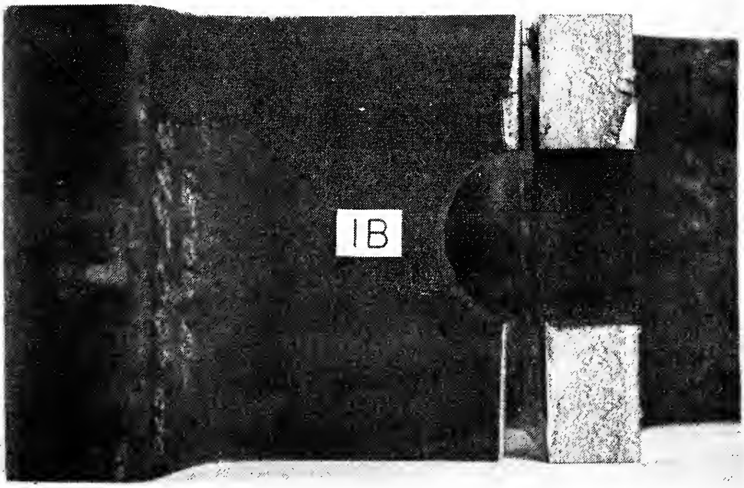


Fig. 16—Typical fatigue failure produced in laboratory.

Fig. 17—Tool for peening edge of bolt hole.

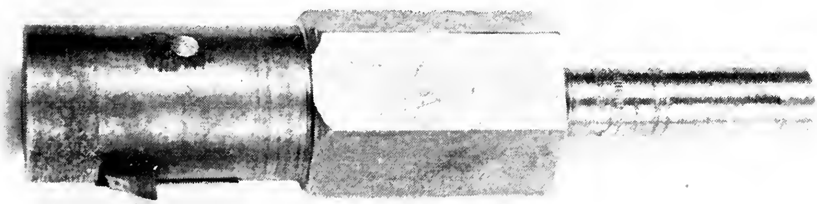


Fig. 18—Cutter for chamfering edge of bolt hole.

Report on Assignment 10

Service Performance and Economics of 78-Ft Rail; Specification for 78-Ft Rail

Collaborating with Committee 5

L. R. Lamport (chairman, subcommittee), E. L. Anderson, T. A. Blair, B. Bristow, C. B. Bronson, B. Chappell, C. J. Code, J. C. DeJarnette, R. A. Emerson, C. J. Geyer, J. K. Gloster, J. L. Gressitt, S. R. Hursh, J. C. Jacobs, N. W. Kopp, Ray McBrian, B. R. Meyers, E. E. Oviatt, R. E. Patterson, G. A. Phillips, R. B. Rhode, E. F. Salisbury, I. H. Schram, A. A. Shillander, W. D. Simpson, A. P. Talbot, R. P. Winton, Edward Wise, Jr., J. E. Yewell.

This is a progress report, presented as information

Service Tests

This is a report of annual measurements to determine the comparative wear and batter of rail joints on two service test installations of 78-ft rail. One test installation is laid with 115 RE rail and is on the eastbound main track of the Chicago & North Western Railway near Calamus, Ia. The 78-ft rail test section is located between M.P. 32 and 33; the 39-ft rail section between M.P. 28 and 29. The other test installation is laid with 133 RE rail and is on the eastbound main track of the Pennsylvania Railroad between Hamlet and Hanna, Ind. The 78-ft rail test section is between M.P. 400 and 401; the 39-ft rail test section is between M.P. 399 and 400. Both test sections are on tangent track. The 115 RE section has headfree-type 36-in joint bars and the 133 RE section has 36-in head-contact-type bars. The 78-ft rails are two 39-ft rails pressure butt welded by the Oxweld process.

The field work, analysis of data and preparation of this report were carried out by the Engineering Division research staff of the Association of American Railroads, under the direction of G. M. Magee, director of engineering research, and K. H. Kannowski, metallurgical engineer.

The initial measurements were made during June 1952, and the results of the data reported herein combine the initial measurements and measurements taken during June 1953 and 1954. Measurements were made of rail surface profile, joint camber, and out-to-out distance of bars for determining the amount of rail-end batter, joint droop and fishing surface wear. Since the 78-ft rails were formed by welding, profile measurements were also taken of 10 welded joints of the south as well as the north rail. Similar measurements were taken on adjoining 39-ft sections to serve as a comparison for the 78-ft rail. Measurements have also been taken of joint gap openings at extremes of temperature, but these are not yet sufficiently completed to present any data.

Discussion of Test Data

The results obtained in the test measurements are shown graphically in Figs. 1 to 8, incl. Since these measurements were taken at a relatively early age in the life of the rail and joint bars, no definite differences in performance can yet be expected. The primary purpose of the test is to determine whether the larger average joint gap that might be expected with the 78-ft rail during the year would tend to result in greater rail batter, joint droop and fishing surface wear, and thereby nullify some of the benefits obtained though elimination of half of the rail joints. It is, therefore, of interest to examine the diagrams critically to determine whether there is any such indication yet in evidence of a greater amount of rail joint wear and rail-end batter with the 78-ft rail.

On the Chicago & North Western Railway, where both test sections have now been in service 6 years and have carried approximately 100 million gross tons of traffic, the average pull-in of joint bars is slightly less for both the north and south rail with the 78-ft rail length. With respect to camber, there is no substantial difference in the change in camber or droop in the two years that the measurements have been made. The average rail surface profiles for 30 joints in both the north and south rail (Fig. 3) show almost an identical amount of batter for both 39 and 78-ft rail on the south rail. For the north rail there is slightly more batter on the 78-ft rail, but the difference is hardly significant.

The service test installation on the Pennsylvania Railroad, which has been in service 4 years, has now carried approximately 80 million tons of traffic. The change in out-to-out distance of joint bars is substantially the same, being very slightly less for the 78-ft rail. There is no difference in the joint droop between the 39 and 78-ft rail sections, as shown in Fig. 6, and the amount of rail batter, as shown by the average rail surface profiles in Fig. 7, is almost identical on both the 39 and 78-ft rail test sections.

Figs. 4 and 8 show the extent to which a perfect rolling surface has been provided for the wheels over the butt welds. These profiles are averages for 10 welds in both north and south rails and, of course, individual welds will show some deviation from the average profiles. Two general characteristics will be noted in these profiles. One is that the rails were not welded in perfect alinement and are, in fact, humped at the welds. Within a length of 36 in the amount of this hump is approximately 0.026 in on both the north and south rail of the C&NW test section, and is 0.038 in on the north rail and 0.052 in on the south rail of the Pennsylvania test section. This is somewhat greater than the humping of the joints with the regular type joint bars, as shown in Fig. 7. There was little hump at the joints on the C&NW section with the regular joint bars. However, a small hump with joint bars is not objectionable as there is a tendency for this to decrease as the bars become worn in service. In addition to the hump of the welds, it will also be observed that there is a deviation in the profile from a smooth curve. There is a slight depression about 4 in each side of the weld. The amount of this depression is not very much, but it is sufficient to produce some impact effects. It varies from 0.002 to 0.010-in. in the average profiles shown.

Conclusion

Length of service has not been sufficiently long on these two service test installations to bring out any outstanding differences in the performance of the 39 and 78-ft rail joints, and the only conclusion that can be drawn at present is that the rate of wear, droop and change in out-to-out distance are substantially the same for both rail lengths.

(Text continued on page 986)

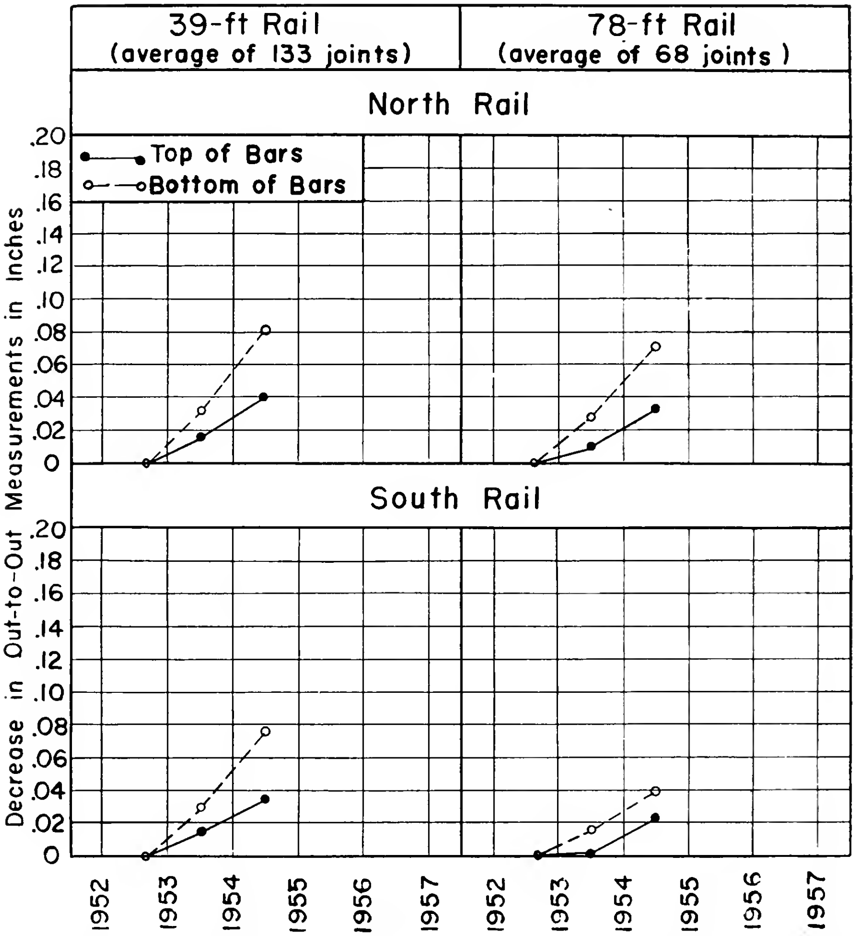
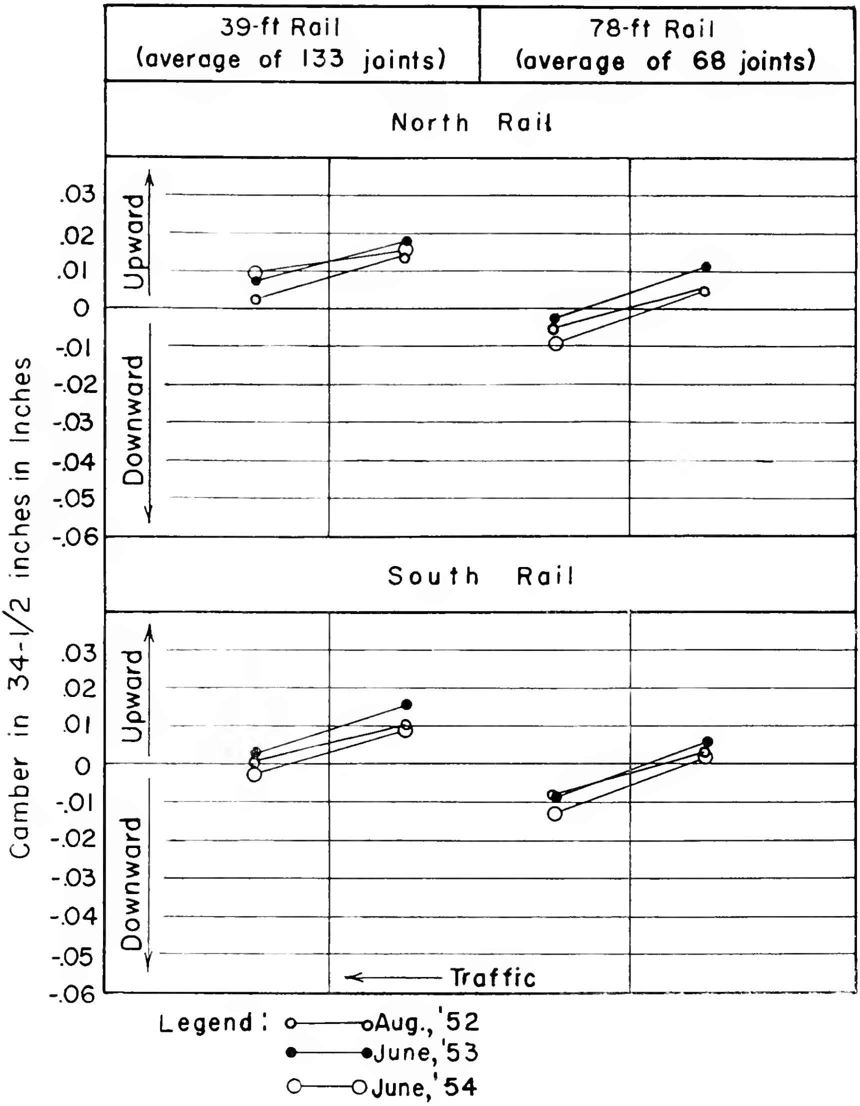
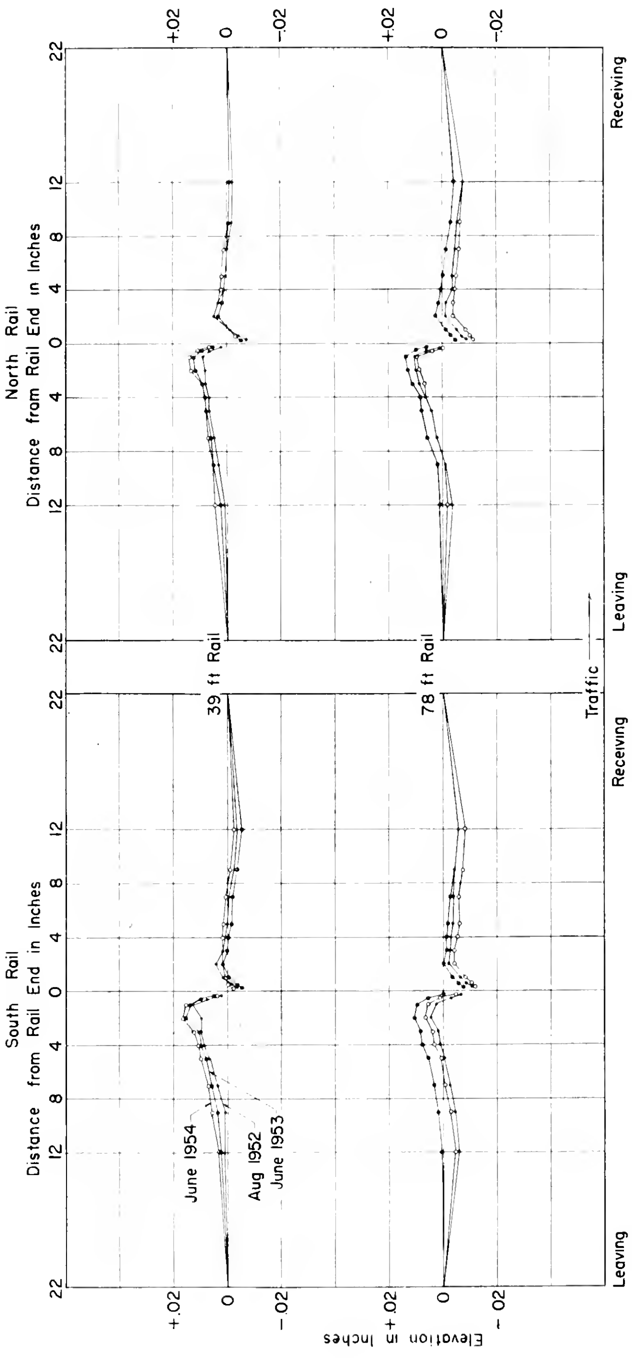


Fig. 1 — Change in Out-to-Out Distances at Middle of Joint Bars, C&NW Ry.



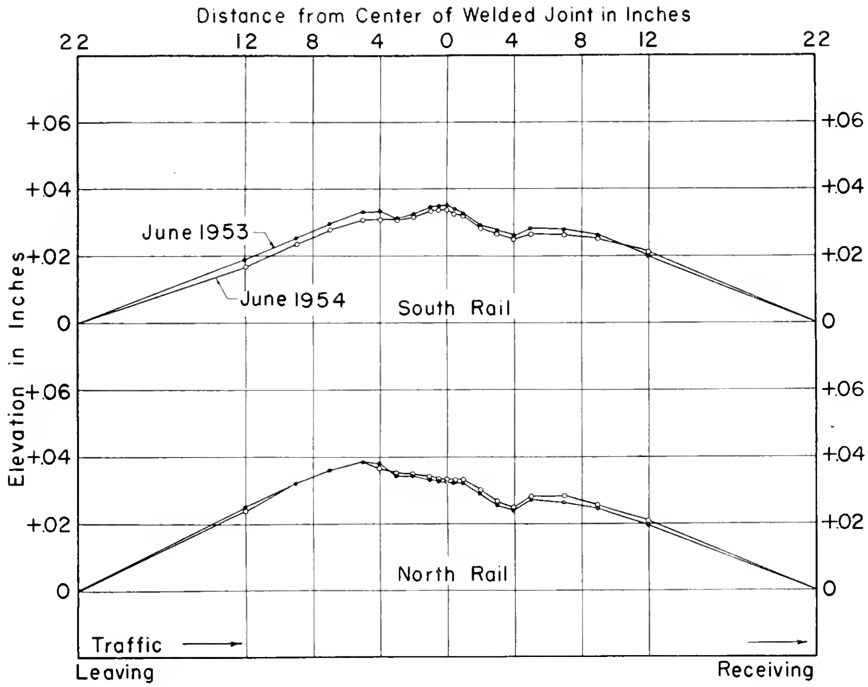
Note: Camber readings are taken 1/2 inch from rail ends.

Fig. 2 — Top of Rail Camber in 34-1/2 inches, C & NW, 1952



Note Profile elevations are the average of 30 joints of each rail

Fig. 3 – Rail Surface Profile, C&NW Ry, 1952 to 1954



Note: Profile elevations are the average of 10 welded joints of each rail.

Fig. 4— Welded Joint Surface Profiles on 78 ft Rail, C&NW Ry 1953 to 1954

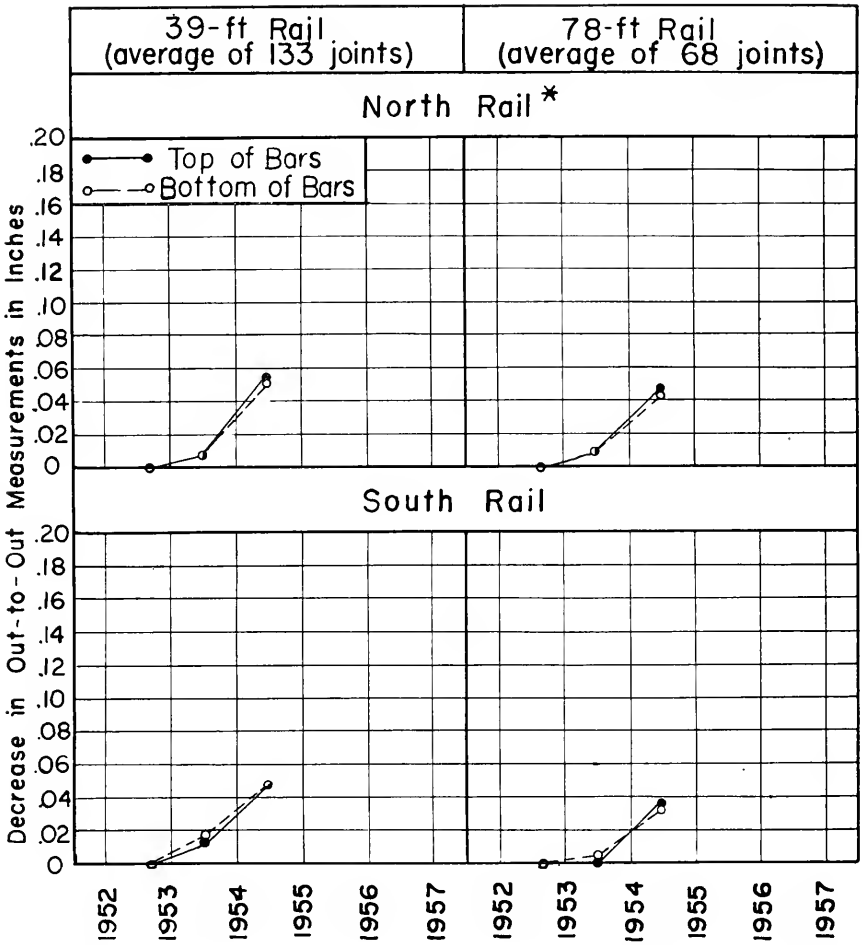


Fig.5 – Change in Out-to-Out Distances at Middle of Joint Bars, Penn RR.

*Note: Same change in top and bottom of bars of North Rail from 1952 to 1953.

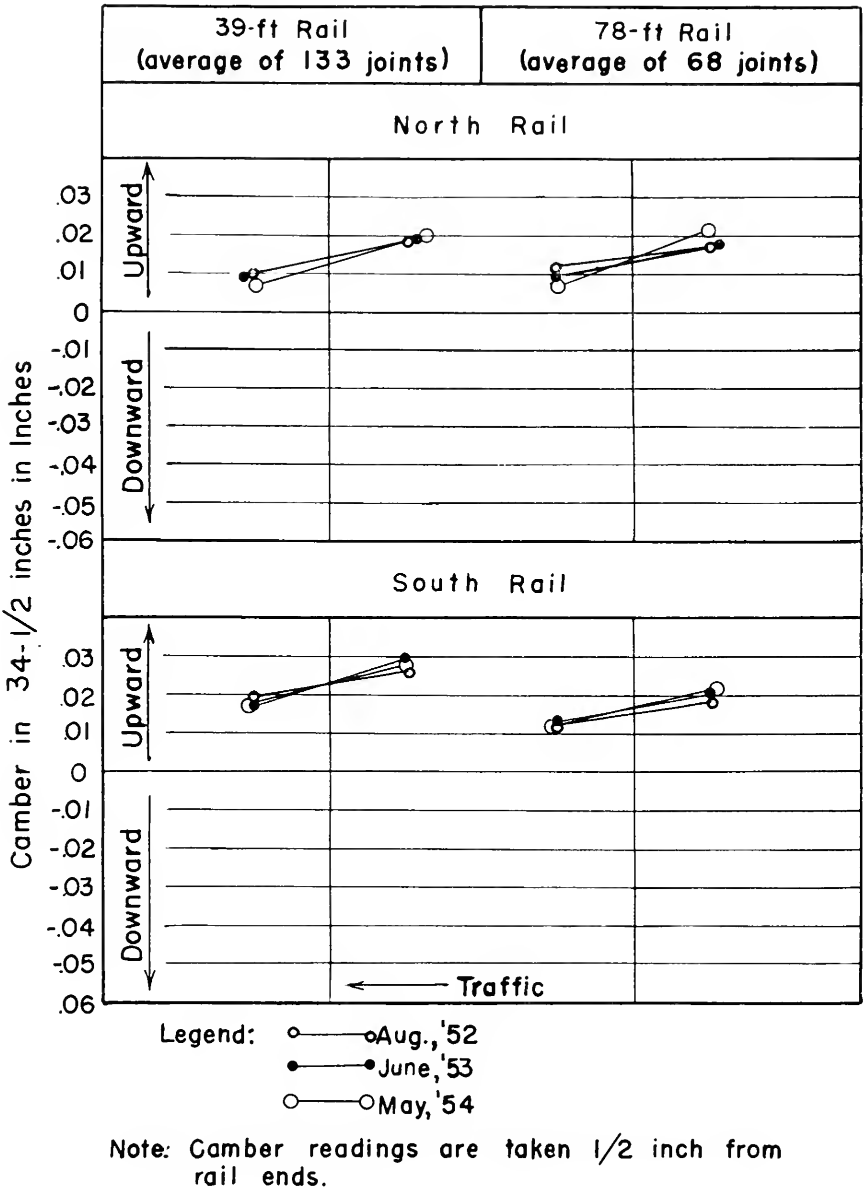
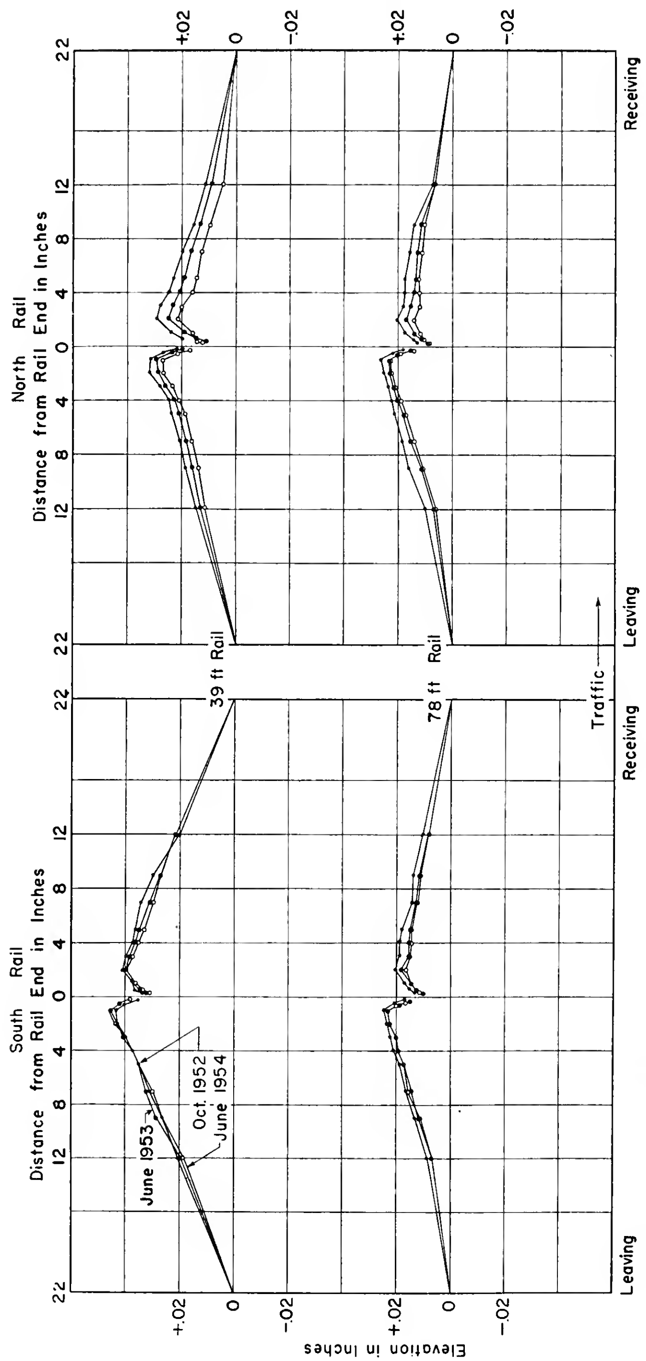
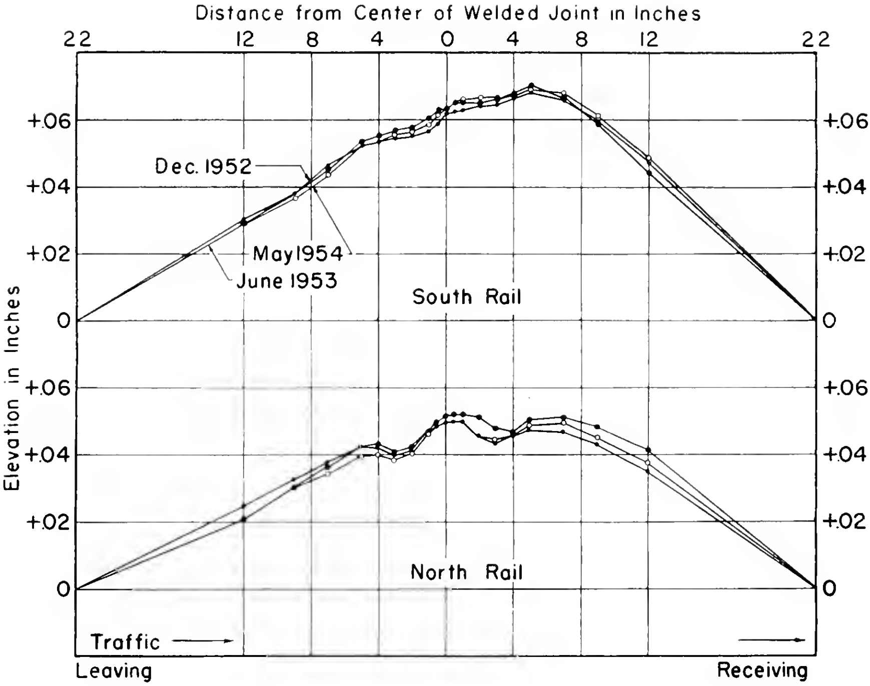


Fig. 6 — Top of Rail Camber in 34-1/2 inches, Penn RR, 1952



Note: Profile elevations are the average of 30 joints of each rail.

Fig. 7 — Rail Surface Profile, Penn RR, 1952 to 1954



Note: Profile elevations are the average of 10 welded joints of each rail.

Fig. 8 — Welded Joint Surface Profiles on 78 ft Rail, Penn RR 1952 to 1954

Economics

On two stretches of 1 mile each on the Pennsylvania Railroad near Hamlet, Ind. and West Lafayette, Ohio, respectively, where conditions are comparable between the 78-ft rail and adjacent 39-ft rail, an annual maintenance labor saving of $300 per mile for the 78-ft rail is reported over a 3.5 year period. No use of material is reported on either the 78-ft rail or the 39-ft rail.

Many installations of 78-ft rail have been made on unstable roadbeds where it is difficult to make a satisfactory comparison with adjacent 39-ft rail on stable roadbeds. The Louisiana & Arkansas reports that in 1952 it laid 10.0 miles of 78-ft, 115-lb rail replacing 39-ft, 90-lb rail over a swamp in Louisiana, following which the track was ballasted with slag ballast, whereas the original ballast under the 90-lb rail was washed gravel. No doubt many factors were involved, but as a result of this installation passenger train speed was increased from 60 mph to 75 mph.

Installations of 78-Ft Rail

Following are listings of known installations of 78-ft rail on American railroads, exclusive of short stretches through highway crossings, along station platforms, over ballast-deck bridges, etc.

Miles Layed By Years

1937	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	Total
1.0	10.0	2.0	10.0	2.0	1.4	9.0	4.0	13.5	....	20.2	62.2	107.5	242.8

Miles Layed By Railroads

Railroads	*Miles*
Central Railroad of New Jersey	8.0
Chicago & North Western	57.2
Chicago, Burlington & Quincy	137.5
Grand Trunk Western	5.1
Kansas City Southern	1.0
Louisiana & Arkansas	10.0
Minneapolis, St. Paul & Saulte Ste. Marie	20.0
Pennsylvania	3.0
Union Pacific	1.0
	242.8

PROCEEDINGS

PROGRAM

Fifty-Fourth Annual Meeting

Palmer House, Chicago

Tuesday, March 15, 1955

★

Morning Session—Grand Ballroom—9:45 to 12:00

Address of President G. W. Miller, Engineer Maintenance of Way, Eastern Region, Canadian Pacific Railway

Report of the Secretary—Neal D. Howard

Report of the Treasurer—A. B. Hillman

Greetings from the Signal Section, AAR, T. W. Hays (Chairman), General Signal Engineer, Union Pacific Railroad

Greetings from the Electrical Section, AAR, R. I. Fort (Chairman), Electrical Engineer Equipment, Illinois Central Railroad

Address—Railroading As a Challenge, by R. G. May, Vice President, Operations and Maintenance Department, AAR

Address—Railroad Interest in Atomic Energy, by Ray McBrian, Engineer of Standards and Research, Denver & Rio Grande Western Railroad, and member of AAR Committee on Atomic Energy

Address—Railroad Research Centers on New Horizons, by G. M. Magee, Director of Engineering Research, Engineering Division, AAR

★

Afternoon Session—Grand Ballroom—2:00 to 4:45

Reports of Committees	Bulletin Numbers
14—Yards and Terminals	518
Address—Handling of Roller-Bearing Cars by Gravity, by A. V. Dasburg, Transportation Engineer, General Railway Signal Company	
16—Economics of Railway Location and Operation	518
25—Waterways and Harbors	518
Address—Fair Play in Navigational Clearances for Bridges, by Paul F. Royster, Assistant to Under-Secretary of Commerce for Transportation	
9—Highways	518
20—Contract Forms	518
11—Records and Accounts	520

PROGRAM

(Continued)

Wednesday, March 16, 1955

★

Morning Session—Red Lacquer Room—9:00 to 12:00

Reports of Committees	Bulletin Numbers
24—Cooperative Relations with Universities	520
13—Water, Oil and Sanitation Services	518
7—Wood Bridges and Trestles	520
28—Clearances	519
30—Impact and Bridge Stresses	519
Address—Fillmore Tests of Static and Dynamic Effects in a Bridge Consisting of Beam Spans Supported on Concrete-Filled Pipe Pile Piers, by R. T. Blewitt, Bridge Engineer, New York, Chicago & St. Louis Railroad	
8—Masonry	519
15—Iron and Steel Structures	520

★

Association Luncheon—Grand Ballroom—12 Noon

Announcement of Results of Election of Officers

Address by N. R. Crump, Vice President, Canadian Pacific Railway on the Railway Industry

★

Afternoon Session—Red Lacquer Room—2:30 to 5:00

Reports of Committees	
27—Maintenance of Way Work Equipment	519
22—Economics of Railway Labor	519
Address—The Engineer's Responsibility for the Future, by W. W. Hay, Associate Professor of Railway Civil Engineering, University of Illinois	

PROGRAM

(Continued)

Thursday, March 17, 1955

★

Morning Session—Grand Ballroom—9:00 to 12:30

Closing Business

Installation of Officers

Adjournment

Report of the Tellers

Presented Wednesday Noon, March 16, 1955

We, the Committee of Tellers, appointed to canvass the ballots for officers and for members of the Nominating Committee, find the count of ballots as follows:

For President

G. M. O'Rourke 1,529

**For Vice-President*

Ray McBrian 1,504

For Directors (first four men elected)

E. J. Brown 947
F. R. Woolford 932
R. H. Beeder 810
C. J. Code 761
G. L. P. Plow 736
W. T. Rice 710
J. F. Marsh 687
W. E. Cornell 590

For Members of Nominating Committee (first five men elected)

**A. B. Hillman 907
R. R. Manion 855
J. M. Trissal 853
E. L. Anderson 841
L. H. Laffoley 825
R. L. Mays 771
D. C. Hastings 741
J. N. Todd 667
F. J. Bishop 590
W. H. Huffman 532

Ten other miscellaneous votes were cast for the various offices listed above.

THE COMMITTEE OF TELLERS,

R. A. BARDWELL, *Chairman,*
ARTHUR ANDERSON
G. A. AUSBAND
J. C. BUSSEY
H. B. CHRISTIANSON, SR.
L. E. CONNER
T. F. CREED, JR.
S. M. DAHL
J. C. DEJARNETTE, JR.
C. S. GRAVES
T. I. GRAY
W. M. HAGER
S. E. HAINES, JR.
E. C. HARRIS
C. I. HARTSELL
H. W. KELLOGG
W. C. KING
T. R. KLINGEL
O. E. MACE
J. DE N. MACOMB
H. C. MINTEER
A. W. MUNT
W. S. RAY
J. E. REYNOLDS
B. J. RICHARDS
E. J. ROCKEFELLER
J. P. RODGER
A. K. ROWNTREE
H. M. SCHUDLICH
J. A. SHEARER
R. M. STIMMEL
L. E. TALBOT
T. A. TENNYSON
A. G. TOMPKINS
S. E. TRACY
J. E. WIGGINS
A. R. WILSON

* Under the provisions of the Constitution, Wm. J. Hedley advances automatically from junior vice president to senior vice president.

** Shortly after the convention, A. B. Hillman, because of unforeseen circumstances, resigned from the Nominating Committee, and R. L. Mays, therefore, became a member of the committee automatically.

PROCEEDINGS

Running Report of the Annual Meeting of the American Railway Engineering Association, March 15–17, 1955, Palmer House, Chicago, Including Abstracts of All Discussion, All Formal Action on Committee Presentations, Specific Papers and Addresses Presented in Connection with Committee Reports, and Other Official Business of the Association

Opening Session—March 15, 1955

The opening session of the fifty-fourth annual meeting convened at 9:45 am, President G. W. Miller* presiding.

President Miller: Ladies and gentlemen: Before I call to order the Fifty-fourth Annual Meeting of our Association, I should like to invite your officers, directors, past presidents, and certain special guests to join me at our Speakers' Tables. I shall be greatly pleased if our two vice presidents will join me at the high-level speakers' table at my right, and if all of our past presidents present will join me at the high-level speakers' table at my left. I would like to ask also that all of our directors and our treasurer come up front and take their places at the second speakers' table directly in front of me. The name plates at the two speakers' tables will indicate the seating arrangement which has been set up for you.

Will the meeting please come to order? This is the Fifty-fourth Annual Meeting of the American Railway Engineering Association, and the concurrent annual meeting of the Construction and Maintenance Section of the Engineering Division, Association of American Railroads.

Before proceeding with the many interesting features on our program, I want to present to you those sitting at our two speakers' tables. As I call their names, I should be glad if they would stand and remain standing until all have been introduced, and I would ask that you kindly withhold your applause until all have been presented. Commencing at our high-level table on my extreme left:

C. G. Grove, president, AREA, 1953–1954, and chief engineer, Western Region, Pennsylvania Railroad, Chicago; C. J. Geyer, president, AREA, 1952–1953, retired vice president- construction and maintenance, Chesapeake & Ohio Railway. T. A. Blair, who has the next seat, was unable to be present with us; he was president in 1951–1952, and is chief engineer, Santa Fe System, Chicago. H. S. Loeffler, president, AREA, 1950–1951, assistant chief engineer, Great Northern Railway, St. Paul, Minn.; F. S. Schwinn, president, AREA, 1949–1950, assistant chief engineer, Missouri Pacific Lines, Houston, Tex.; C. H. Mottier, president, AREA, 1948–1949, vice president and chief engineer, Illinois Central Railroad, Chicago; Armstrong Chinn, president, AREA, 1947–1948, president, Terminal Railroad Association of St. Louis, St. Louis, Mo.; A. R. Wilson, president, AREA, 1936–1937, retired engineer of bridges and buildings, Pennsylvania Railroad.

Now, on my extreme right, Wm. J. Hedley, junior vice president, AREA, and assistant chief engineer, Wabash Railroad, St. Louis, Mo.; G. M. O'Rourke, senior vice president, AREA, and assistant engineer maintenance of way, Illinois Central Railroad, Chicago.

* Engineer maintenance of way, Eastern Region, Canadian Pacific Railway.

The next two gentlemen will be introduced later.

A. B. Hillman, treasurer, AREA, chief engineer, Belt Railway of Chicago and Chicago & Western Indiana Railroad; Neal Howard, Secretary, AREA.

At the lower level table, commencing on my extreme left: M. H. Dick, director, AREA, editor, Railway Track and Structures—western editor, Railway Age, Chicago; E. E. Mayo, director, AREA, and until recently chief engineer, Southern Pacific Company, Pacific Lines, with headquarters at San Francisco, Calif. Mr. Mayo is now vice president of Southern Pacific Pipe Lines, Inc., a newly formed subsidiary of the Southern Pacific, with approximately 800 miles of lines, carrying refinery products from Los Angeles and the El Paso refinery areas to Tucson and Phoenix, Ariz.

S. R. Hursh, director, AREA, and chief engineer, system, Pennsylvania Railroad, Philadelphia, Pa., is unable to be present with us today. Ray McBrian, director, AREA, engineer of standards and research, Denver & Rio Grande Western Railroad, Denver, Colo.; E. S. Birkenwald, director, AREA, engineer of bridges, Western Lines, Southern Railway System, Cincinnati, Ohio; H. B. Christianson, director, AREA, special engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago; B. R. Meyers, director, AREA, chief engineer, Chicago and North Western System, Chicago; G. E. Robinson, director, AREA, engineer of structures, Lines West, New York Central System, Chicago; C. B. Porter, director, AREA, assistant chief engineer, Southern Region, Chesapeake & Ohio Railway, Richmond, Va.; C. H. Sandberg, director, AREA, assistant bridge engineer, system, Santa Fe, Chicago; W. H. Giles, director, AREA, assistant chief engineer, system—construction, Missouri Pacific Railroad, St. Louis, Mo.; H. R. Peterson, director, AREA, chief engineer, Northern Pacific Railway, St. Paul, Minn.

Your head table guests. (Applause)

I should now like to introduce to you two special guests at our speaker's table whom I skipped over purposely in making the introductions thus far. I refer to the two gentlemen immediately to my right, who are the chairmen of the two other sections in the Engineering Division of the AAR.

I present, first, Mr. T. W. Hays, general signal engineer, Union Pacific Railroad, who is chairman of the Signal Section, Engineering Division. (Applause)

I should now like to introduce the second of these gentlemen, Mr. R. I. Fort, electrical engineer of equipment, Illinois Central Railroad, who is chairman of the Electrical Section of the Engineering and Mechanical Divisions, AAR. (Applause)

I shall call on both of these men later for a few remarks.

Last, but not least, I want to give recognition to the ladies in the balcony who have come in to join us at our opening session. We are honored and graced by your presence, and hope that you will not only enjoy the features of our opening session but will feel at liberty to drop in and look down on us during any of the other sessions of our convention. I would particularly invite you to our closing business session on Thursday, beginning about noon, when our new officers for the coming year will be installed. I want you to know that you are also welcome to participate in our annual luncheon in this room tomorrow noon.

Other features of the program set up for you have been brought to your attention in your registration room on the third floor. We hope that you have a wonderful time while you are here, and that you will come back another year.

The first official business of our annual meeting is consideration of the minutes of our last annual meeting. These minutes were printed in Vol. 55 of the AREA Proceedings, for 1954, a copy of which was furnished to each member, so unless I hear some correction or objection, we will dispense with the reading of these minutes. Hearing no corrections or objections, I declare the minutes approved as printed in the Proceedings.

Address by President G. W. Miller

Members of the American Railway Engineering Association, Ladies and Guests:

For many years it has been the practice at this opening session for the Association President to make a detailed report on the important events of the current Association year. During recent years, however, this has been increasingly unnecessary because our monthly AREA News keeps us well informed and up to date. My remarks about the past year, therefore, can be brief. I will also discuss some of our convention highlights and, in conclusion, touch on future problems.

In every respect your Association has continued to move forward and supply the railway industry with the important technical advice necessary to keep pace with other modes of transportation. It has not been a year of startling accomplishments but one of steady, healthy growth, all due to a continued high level of support by the industry, and more particularly to the willingness of committee chairmen and subcommittee chairmen to give freely of their time and effort. This has been stimulated by your officers appropriately recognizing the efforts and results of men on all working committees.

In spite of a small decline in railway revenues and a slackening in construction, the membership has continued to increase, and I am glad to report that on February 1, the end of our membership year, we had 3278 members on the rolls, an all-time record. This number includes 436 Life Members, 2381 Members, 274 Associates and 187 Junior Members, the last two classifications having declined steadily since 1951.

I am convinced that railway managements recognize the value of the work being done by our Association; otherwise we might have expected a decline in membership, resulting from a decline in net earnings. During the past year, chief engineering and maintenance officers were requested to review the inherent benefits which lie in Association membership, with the result that more men were recommended for membership and for committee work.

Our committees have become so active that the limit of 60 members was attained on 8 of them, and your officers promptly recognized the men on waiting lists by increasing the limit from 60 to 70 men per committee. I am pleased to report that this year our Association established an all-time record of 1078 members on 23 committees.

The work of these committees will be revealed to you during the next three days, so I need not describe the many important matters to be discussed, as you have Bulletins and programs to which you can refer.

With the beginning of the new calendar year 1955, your directors were quite concerned about the possible effect of pass restrictions for business purposes, including travel to committee meetings, by a few eastern railroads. I am happy to report to you that there has been no noticeable reduction in committee attendance since these restrictions were put into effect, and at least one senior engineering officer has laid down the policy that AREA work must go on, and appropriate arrangements are being made to permit its members to travel on other roads.

As this meeting proceeds, you will notice that committee chairmen are being honored and recognized for their interest and effort on behalf of the Association. The new chairmen will receive an attractive gavel, and all chairmen will be guests of the Association at the luncheon at noon tomorrow. An honorary degree of membership has been established for those who have rendered outstanding service on the Committee on Convention Arrangements for 10 years or more. This committee is the force behind the scenes at this convention.

Your Association's technical activities are outlined in 7 Bulletins, numbered 515 to 521; in the Manual Supplement to be issued after the annual meeting, and in the revision of its Portfolio of Trackwork plans. But, in addition, we have published and sold many other articles and specifications; in fact, over 28,000 were sold during the past year.

Your treasurer will report later regarding our financial position, which, I am glad to say, is excellent.

Engineering research, which is sponsored by our committees, will be discussed by G. M. Magee, director of engineering research. I must compliment the staff at the research center of the Association of American Railroads for the sympathetic understanding of our many maintenance problems which have been and are being solved in both field and laboratory.

Now may I briefly draw your attention to our program, and particularly to two of the convention highlights, both of which will be of interest to all.

The first is a discussion on the possible use of nuclear energy by the railroads. It will be conducted later this morning by men who have done considerable research in this field.

The second is a panel discussion on the use of rail lengths greater than 39 ft. This discussion will be by men who have spent a lifetime on the subject and is sponsored by the Rail committee and the Special Committee on Continuous Welded Rail. It will be held in this room on Thursday morning.

In recent years there have been two questions raised about our convention programs —why so little discussion and what can be done about it? The first is answered, I think, by the lack of time in our program for discussion and the accepted fact that any subjects reviewed by our committees are thoroughly discussed by a group of experts at the committee meetings. Possibly, also, some who are not members of the committee may feel that they should not question a committee report without detailed consideration. These points may be valid, but your officers feel that more discussion would be beneficial and a specified time has been allotted in our program for questions. In fact, one-tenth of the presentation time is allotted for discussion, and your presiding officer will draw this to your attention at the end of each committee report, so please speak up.

Now, what of the future?

Recently, I was interested to learn that in 1905 there were only 78,000 automotive vehicles operating in this country. Today there are over 58,000,000, and it is estimated that 1 in every 7 persons is engaged in the automotive highway transport industry.

We had 25,000,000 horses and mules in 1905 but only 5½ million last year. I am not sure how they were counted but in any event the comparison is quite interesting. You see, a mule eats as much food as 2½ men, and as our population increased we just had to find more food.

There were no civil aircraft in 1905, but today the number registered exceeds 89,000.

One subject brought into sharp focus by these statistics is the fact that competition between the railways and other modes of transportation will increase and be keen in the years to come. In 15 years the highways may be so crowded that the truck operators will be glad to ride piggy-back on our railway flat cars, and I believe it will soon be very difficult to land a flock of cargo mail planes on our now too busy airports. We must not assume, therefore, that all or even a portion of our freight traffic will be lost.

Since the turn of the century science and technology have advanced so rapidly and in so many directions that it is almost impossible for anyone to forecast what will happen 50 years from now, but we can all look 5 or 7 years beyond 1955, and we have some men on our committees who can see at least 10 to 15 years ahead.

The point I wish to make is that in the foreseeable future we will have stiff competition which, in turn, may restrict the amount of money available for maintenance of track and structures. We must determine, therefore, how the old hand tools, such as the shovel, the pick and the spike maul can be turned in for credit. If you see a group of men slowly pumping a hand car or mowing grass with a scythe, take notice, because there are less costly means of doing this work. These are tangible ideas, and I am sure you will see many machines at the National Railway Appliances Association exhibit at the Coliseum which will suggest how work can be done more efficiently.

Now let us look at some of the intangible items of high maintenance expense.

Why do we paint our bridges so frequently? Surely there are synthetic, resinous paints that will stick to steel for the life of the structure.

Our joint maintenance prob'em continues to be the most expensive item in preserving the life of rail and joint ties, since rail lengths longer than 39 ft cannot be secured from the mills at this time. There might be a semi-flexible material that can be used to weld the joint bars to each rail, just as two pieces of plywood are fastened together.

For years I have been able to read the time at night by looking at the luminous dial on my wristwatch, but we on the railways still have to fill the switch lamps with coal oil once a week and replace a signal light bulb every 2000 hours. Can someone in this audience devise a way of providing a unit to store up light during the day and give it off at night, all with a fraction of the expense we now incur?

But of all the problems that must be faced, the most difficult one is to lift ourselves out of the groove between those two rails and look around to see where we are going.

As with all practical problems, we should concern ourselves with our life blood, which must be kept virile. To help solve the problems of the future, we must recruit more active young men into the ranks of our Association and our profession. No freak of salesmanship and no financial pressure can suddenly create a group of adequately trained engineers. They emerge irresistibly out of long, patient and sustained effort.

The future of our economic supremacy and of the railway industry will soon rest upon the creative ability of our younger engineers rather than upon the rich, natural resources we once possessed.

In conclusion, may I say that I am deeply conscious of the honor that has been bestowed on your neighbor country to the north, in selecting one of its citizens to be your president. I have counted it a great privilege to serve with the officers and directors which the membership of the Association has selected.

No words of mine could adequately express the measure of assurance which I have in the future of the American Railway Engineering Association—the quality of service we have rendered in the past will surely permit our Association to continue to prosper and increase its assistance to our industry. We stand at the threshold of many new ventures, with the use of nuclear power, thermal heat storage of the sun's rays; in fact, the whole horizon is charged with challenges to the engineer's vision, and his future is limitless.

The challenge of the future is upon us.

President Miller: At this time I would like to call upon our secretary for his report. Mr. Howard, would you please present the report of the secretary of our Association?

Secretary's Comment

Mr. President, members and guests: It is good to have been your secretary another year. It was a rugged year in some respects as you have continued to grow and have taken on more and more, but it was an interesting year for me. It was a great privilege and pleasure to work with your president and Board.

We are all part of a great Association, and I am pleased to substantiate what President Miller has already told you—that the Association has had another good year.

Time will not permit me to detail the secretary's report, even if I would. Were I to do so, I am sure it would cut Gerald Magee off the end of this morning's program, as we so nearly did last year. I don't want this to happen again—and neither do you.

The secretary's report is all "spelled out" in 16 pages of the March Bulletin, where I am sure many of you will want to read it. Suffice it to say here as President Miller has told you—our membership has further increased, standing at an all-time high, in spite of the fact that we lost many valued members during the past year through death. Membership on committees has further increased; committee activities and procedures have expanded; your Board of Direction has adopted a number of innovations in Association procedure and has enlarged the services of the Association; your Manual is in splendid condition and enjoys its highest prestige; and your Association is in a sound financial condition.

I do not ask that you take my word for any or all of this. Many of you already know it, and it is all a matter of record. But for your satisfaction, I would like to quote just a couple of lines from the report of the Association's long-standing, capable, interested and deep-delving auditors, who each year not only go over the books of the Association, but who take a critical look at all of the Association's activities and frequently come up with helpful suggestions or ideas. I quote in part from that report:

> "It was a pleasure to us, as we are sure it was to you, to see the Association have such an excellent year, and we hope it continues this year. During good years it is sometimes difficult to find things wrong, so perhaps that is why we have no recommendations or suggestions to offer at this time."

(Signed) C. A. Bick,
Vice President—Operations
Chicago, Indianapolis & Louisville Railway
P. D. Mitchell,
Travelling Auditor
Illinois Central Railroad

The fact remains that they couldn't find things wrong and had no recommendations to make, which was a source of satisfaction to your secretary's office—and I hope also to you.

Deviating from the program for a moment, Mr. President, if I may, if our auditors are here this morning, and no doubt they are, looking for some opportunity to criticize or improve operations, I would like to recognize them by asking them to stand—Mr. Bick—Mr. Mitchell. (Mr. Bick was present and stood.)

I have already said that our membership, which totaled 3278 on February 1, is at an all-time high. It is, but I am not satisfied that it is enough. This total of 3278 includes only about 2350 senior members who are active in railroad service, which I am certain is far from the saturation point in the interest of the Association, the railroads, and railway engineering and maintenance officers themselves. It is disconcerting to me that the personal columns of the trade publications each month list the names of highly qualified railroad engineering and maintenance officers who have not availed themselves of membership. It is evident that we still have a job to do.

Neither am I satisfied that we are reaching properly and adequately the young junior engineers who are employed by the railroads each year. Only 41 new Junior Members were taken into the Association in the last year ended February 1, 1955, and

39 the year before. We lost more than that number through resignations, or being dropped. Assuming that these young men have entered railroad service to make the most of it for themselves and their companies, it seems reasonable to believe that nearly 100 percent of all of the young technical graduates employed by the railroads each year—apprised of the value of membership in the AREA—would want to make application for membership.

Recognizing this situation, your Board of Direction is endeavoring to work out some fool-proof plan wherein the value of AREA membership can be early brought to the attention of every junior engineer employed by the railroads. In this we are not thinking selfishly of the Association; we are thinking of the welfare of the young engineers themselves, their railroads and the railroad industry. But we are also thinking of the Association, because after all our Association is only a means to an end, and will continue to be great only as it fulfills its purpose to the greatest possible extent.

In closing let me remind you that we in your secretary's office consider ourselves your service department. There is much that we can do, and we are trying. There are things that we can't do for you—things that you wouldn't want us to do even if we could, but we stand ready to do everything possible to help you, to help the Association, and to make the coming year even more successful than the past one.

President Miller: Thank you, Mr. Howard.

I'm sure that many members of the Association will want to read carefully the entire report of the secretary as published in the March Bulletin, which was mailed about March 1, and which will be in your hands upon your return home, if it has not already been received.

The treasurer's report will now be presented by our treasurer, Mr. A. B. Hillman, chief engineer, Chicago & Western Indiana Railway, and the Belt Railway of Chicago.

Treasurer's Report

Mr. President, members and guests: Examination of the Financial Statement, Report of the Treasurer, and the General Balance Sheet for the Calendar Year 1954, as published in the March issue of the Bulletin, indicates that the Association is in good financial condition, thanks mainly to the unprecedented sale in 1954 of the reprinted Manual. Total receipts for the year were $17,745.96 in excess of total disbursements. However, it should be borne in mind that the Association incurred a deficit of $9,034.79 in 1953, due to Manual reprinting, which figure offsets in large part the excess receipts in 1954. Also, whereas the General Balance Sheet for 1953 showed as assets a Manual inventory item of $15,880, the same item for 1954 is only $5,406.40, due to the depletion of this inventory through Manual sales. Furthermore, total assets of the Association for 1954 were only $4,786.89 higher than for 1953.

It is well that the year 1954 was an excellent one financially for the Association, since, due to revision in the majority of the trackwork plans contained in the Association's Portfolio of Trackwork Plans, and a depleted supply of those plans not revised, it will be necessary to completely reprint the Portfolio of Trackwork Plans in 1955 at large expense. This reprinting will, no doubt, result in the Association again in 1955, as in 1953, incurring higher expenditures than receipts. If the Association is also to finance in 1955 a recruitment brochure for distribution among the undergraduates of the engineering colleges and universities, as is proposed by your Committee 24—Cooperative Relations with Universities, in its current report, it is a certainty that, financially, it will end the year 1955 with a substantial deficit, which makes it all the more fortunate that the Association had an exceptionally good year financially in 1954.

President Miller: Thank you, Mr. Hillman. I'm sure our members derive considerable satisfaction from your assurance that our Association is in good financial condition, thanks largely to the sale of Manuals during the past year.

You have heard the reports of the secretary and treasurer. What is your pleasure with respect to these reports? I shall be glad to entertain a motion that they accepted.

(Motion was regularly made and seconded that the reports of the secretary and treasurer be approved; the motion was put to a vote, and carried.)

Tribute to J. M. R. Fairbairn and E. M. Hastings

President Miller: Our secretary has already made brief reference to the death during the past year of a number of our valued members, and a complete list of these members appears in the secretary's report. This list contains the names of two of our Past Presidents and Honorary Members to whom we would like to pay special tribute. I have asked Past President Geyer if he would present this tribute.

C. J. Geyer (Retired vice president—construction and maintenance, Chesapeake & Ohio): Mr. President, gentlemen of the Association: At this time it is the privilege of the members of this Association to pay loving tribute and respect to our associates and co-workers in this Association who have passed on to their reward during the past year.

Forty-six members answered the call to the Great Beyond since our convention one year ago. Included in this number were two of our outstanding members, John Morrice Roger Fairbairn, retired chief engineer of the Canadian Pacific Railway, and Past President and Honorary Member of this Association. Mr. Fairbairn died May 27, 1954. A memoir in his honor appears in Bulletin 517, page 323.

Also, Edgar Morton Hastings, retired chief engineer of the Richmond, Fredericksburg & Potomac Railway, and Past President and Honorary Member of this Association. Mr. Hastings died November 21, 1954. A memoir in his honor appears in Bulletin 521, page 987.

Both of these gentlemen, each in his generation, served this Association with honor and dignity, and with great benefit to our organization and its members, especially, to our young men, Mr. Fairbairn as President in 1925–1926, and Mr. Hastings as President in 1939–1940.

Our Association is blessed and is thankful for having had such men as our fellow workers.

In the past year we also suffered the loss of one of our charter members, Mr. Frank Lee Nicholson, charter member and retired chief engineer of the Norfolk–Southern Railway.

Will you all please stand and offer one moment of silent prayer for all of our 46 departed comrades? (The audience arose).

Greetings From the Signal and Electrical Sections, AAR

President Miller: Since this is not only the annual meeting of the American Railway Engineering Association, but also the concurrent annual meeting of the Construction, and Maintenance Section of the Engineering Division, Association of American

Railroads, it is highly appropriate that we should have invited to be with us again on this occasion representatives of the other two sections of the Engineering Division, namely, the Signal Section and the Electrical Section. We continue to have a happy and profitable relationship with these two sections, a relationship which I am sure will continue long into the future.

The chairmen of these two sections have already been introduced to you, but I should now like to recognize them further and give them the opportunity to say a few words of greeting, should they desire.

The chairman of the Electrical Section is Mr. R. I. Fort, electrical engineer of equipment, Illinois Central Railroad. Mr. Fort.

R. I. Fort: Mr. President, members of the American Railway Engineering Association and guests: I bring you greetings from the Electrical Section.

Railroads are pretty much taken for granted in America, although they play such a vital role in our economic structure. Just a bit over 120 years ago the first little "tea-kettle" started running on rails, moving things and people. A half century was spent in extensive building of new track into undeveloped territories. During the next half century extensive development gradually changed to intensive improvement of facilities and equipment.

I read an editorial in the Society of Automotive Engineers Journal recently which quoted a member as saying that he views the future with an open mind and a degree of optimism. Such a man attracts new ideas from his associates. They let him in on untried ideas they are not ready to prove. New projects are likely to be born in his presence.

Electronics has been noisily revolutionizing equipment, methods and processes over the past 50 years, and now electronics itself is being revolutionized by a small gadget called the transistor.

The transistor holds promise of making possible or practicable the use of electronics to better control many machines now used by railroads. This and other technical developments are being explored by the Electrical Section to find applications for improvement.

The Electrical Section views the future with an open mind and a degree of optimism. We are proud of our connection with your distinguished Association, and are ready to assist you in any way possible. I appreciate the opportunity to come before you at this opening session, and wish you well in your forthcoming deliberations. (Applause).

President Miller: Thank you, Mr. Fort.

We should now be pleased to have a word from Mr. Hays, chairman of the Signal Section, and General Signal Engineer of the Union Pacific.

Mr. Hays: Mr. President, members of the Association and guests: I appreciate very much—as a representative of the Signal Section—the opportunity to attend your opening session and to bring you the heartiest of greetings from our signal group, and the assurance that we will continue to cooperate with you in all matters in which we are mutually concerned. We hope our relations in the future will be as cordial as they have been in the past. Thank you. (Applause)

President Miller: Thank you, Mr. Hays. We appreciate your being with us this morning, and would be pleased if both you and Mr. Fort would remain with us and participate in the features of our annual meeting to the extent that your time will permit.

Greetings From the National Railway Appliances Association

President Miller: As you all know, our friends in the railway supply industry have prepared a large exhibit of materials, equipment and devices in conjunction with our annual meeting, at the Coliseum, here in Chicago, under the auspices of the National

Railway Appliances Association. We deeply appreciate this tremendous effort on the part of our supply friends, and I should like to recognize at this time the president of the NRAA, Mr. Jess Mossgrove, and invite him to the speakers' platform for a few words of greeting and perhaps an invitation which he may wish to bring to us to attend the exhibits at the Coliseum.

Jess Mossgrove: Mr. President, members and guests: I want to thank you on behalf of our association for this opportunity to extend our greetings to your Association at the opening of your fifty-fourth annual convention.

We invite you to come and see us at the Coliseum, not once, but many times, to inspect the equipment and material we have on display there, and to visit with your many friends among the railroad supply fraternity.

We have prepared for your inspection a very elaborate and comprehensive display of equipment, and you will find there many new and improved machines to consider. Our show this year is an assured success as far as space rentals are concerned, as we have filled both the Coliseum and Annexes. To have a complete success, we need only your attendance, and we are hopeful that you will find the time to come and see us, often, early, and to stay late.

I believe you are all familiar with the existing agreement between our association and our companion associations—Track Supply and Bridge and Buildings—whereby exhibits are spaced every 18 months, alternating between our association in March and the Track Supply and Bridge and Building jointly in September. Your Association, the Roadmasters' and Maintenance of Way Association of America and the American Railway Bridge and Building Association have been most cooperative, and have indicated their approval of this spacing of exhibits.

We are most grateful for your cooperation and understanding. Your Association and ours have worked together harmoniously for a good many years, and the ties that bind us ever closer together have become stronger as time goes on. It is really an honor and a pleasure to work with you, and to supplement your efforts in every way that we can to provide the finest in equipment for the world's finest railroads.

Our best wishes, gentlemen, for a most satisfactory and interesting convention, and we'll be looking forward to seeing you at the Coliseum. Thank you. (Applause).

President Miller: Thank you, Mr. Mossgrove. Your association has set up a wonderful exhibit, which I had the pleasure of seeing yesterday. I know you can count on a visit from all of our members. In fact, I think you'll wish you had a larger building before the week is out.

Since the American Railway Engineering Association functions also as the Construction and Maintenance Section of the Engineering Division, AAR, within the Operations and Maintenance Department of that Association, we are very pleased to have with us again this year, to bring us a timely message, Mr. R. G. May, vice president of the Operations and Maintenance Department, AAR.

You will recall that Mr. May was with us at our annual meeting last year, having become connected with the Association of American Railroads in 1953, in his present capacity, succeeding our good friend, J. H. Aydelott. Mr. May is an engineer by training and experience, and came to the Association of American Railroads from the New York Central System, where, at the time, he was vice president in charge of operations and of maintenance. We are pleased and honored to have Mr. May with us again this morning. He will address us on Railroading As a Challenge.

Railroading—A Challenge to Engineers

By Richard G. May

Vice President, Operations and Maintenance Department,
Association of American Railroads

One year ago it was my pleasure to appear before the American Railway Engineering Association for the first time. We were then in a period of declining traffic as a result of adjustment from a wartime to a peacetime economy. With decreased carloadings and revenues, many of the railroads in areas more seriously affected were reviewing their maintenance programs with a view toward effecting essential economies. They were also taking a long look at the whole problem of roadway costs. For when railroad managements are confronted with problems, they are not so fortunate as, say, a Chicago White Sox pitcher facing Ted Williams or Mickey Mantle. The pitcher can turn to the dugout and, generally, if he has loaded the bases, is waved to the showers. The railroad manager must stay in there and pitch all the harder.

The railroads met the economic problem and pitched their way out, and the prospects today are very much different. Carloadings are on the increase, and the picture is generally brighter and more optimistic. We cannot, however, take the leveling out of one short, though severe, sag in the economic curve as having permanently solved the problem. It is for this reason that I have chosen as my topic "Railroading—A Challenge to Engineers."

The record shows commendable accomplishments by the professional railroad engineer. The engineer of the early part of the century accepted and met the challenge of that time—the challenge to extend trackage over all the nation, to reach potential industrial areas by the most favorable routes, and to provide building sites for industries to come. Favorable routes permitting economic construction and operation were necessary to compete with other railroads and the waterways. The engineer of that time realized that rail transportation was a national and perhaps international necessity—that free interchange of traffic over a national rail network was a must. This was brought about by standardization of track gage and equipment.

There was no time, however, to bask in the glory of accomplishment. It was around that time that motor vehicles began to appear. And a short time later came the airplane. With the wisdom of hindsight, we now laugh at the fact that neither the airplane nor the automobile were taken seriously at their early appearance. But few then thought that they would develop to the place where they would be considered a necessity for transportation.

The thought has been expressed in some areas and among some groups that busses, trucks and airplanes have made such serious inroads in the railroads' traffic that we are part of a static industry. We cannot agree that railroading is a static industry. Nor can anyone else who has beheld the immense changes wrought in railroad plant and operating practices during the last few years.

But growing competition has posed a wholly new challenge to the members of your profession. To take one concrete example; we are all familiar with the experiments to carry first-class mail by air and much short-haul mail by trucks. These items are worth our consideration, since their effect will again tax the imagination, incentive and initiative of the railroad officer, as well as increase the responsibilities of every employee, in an effort to retain such traffic.

The engineer can no longer isolate himself and deal only with design layouts, cost estimates and preparation of reports. He must have a broad knowledge of all items pertaining to the industry and detailed knowledge of his own railroad. He should know the nature of his railroad's traffic, the services provided, and any weakness or deficiencies in the physical characteristics of the road which detract from service or add to operating costs. To know this, he should be familiar with statistical data of train and yard operation. He should be familiar with all groups of accounts included in the total operating ratio. Such knowledge forms the firm base on which constructive action is built.

The engineer familiar with yard and road operation can find many ways of simplifying and expediting switching by rearranging crossovers and other tracks in yards. Studies of road operation will enable him to recommend improvements which will also contribute toward superior service.

It would take considerable time to enumerate all of the duties and responsibilities of the engineer, but there is one very important challenge which I would like to single out for comment. The success of a good administrator depends in part on ability to develop well trained personnel. He must prepare to fill vacancies in his own department and, in addition, be prepared to furnish talent elsewhere if requested. Many railroads today are recruiting operating and maintenance personnel from the engineering ranks. Some have been successful in securing students to work on a vacation or part-time basis to develop their interest in railroading as a career, and have been able to employ some of these students on a full-time basis after graduation. As an aid in interesting undergraduate engineers in railroading, the AREA is now preparing a brochure about the railroad field for distribution in technical schools.

Railroading needs qualified engineering specialists—for, as I said before, there can be no question but what the railroad industry is an expanding, vibrant industry, full of technological change. In 1921 railroads handled 309 billion ton-miles of freight—and, in 1953, 609 billion ton-miles. This doubled traffic was handled with 578,000 fewer freight cars and 32,000 fewer locomotives.

During the same period the trackage protected by automatic block signals increased from 62,445 miles to 110,404 miles, and centralized traffic control was installed on 22,142 miles of track. The improvements during this period made it possible to develop an efficiency of operations with a resultant economy that permitted rates to be maintained at a competitive level with forms of transportation which enjoyed the lopsided advantage of having part of their costs paid by government through subsidy.

The competitive challenge is now confronting us on many fronts—over the road, on inland waterways and in the air. One example of the seriousness of this situation is pointed up by the $101 billion highway program recommended by the Clay Committee. An essential part of this proposal is an interstate system of about 40,000 miles of superhighways. For just this one big segment, the Federal Government is being asked to spend $25 billion in 10 years. Additional expenditures for other road systems would raise total Federal spending to some $31 billion. If you don't think that's a lot of money, consider this: the Federal share alone is more than the net investment of the entire railroad industry, a business more than a century old.

I would like to emphasize that railroad men are no less in favor of good roads than their neighbors, for *we* are motorists, too. But as both railroaders and motorists, we believe that heavy vehicles should begin paying charges for the use of public highways which are realistically related to vehicle weights and mileage traveled. Railroads move vast quantities of freight over their own steel highways, which they build and maintain themselves—and on which, in addition, they pay hundreds of millions of dollars in property and other taxes. While heavy trucks may be unable to build *their* own highways, simple justice to taxpayers and other highway users requires that they pay user charges which take fully into account the abnormal weights they impose on roads, the abnormal use they make of them and the abnormal costs they necessitate in road building and maintenance.

Unless some such adequate user charge is included in plans for vast highway spending, heavy trucks will continue to pay far less in road-use taxes per ton-mile of travel than passenger car owners, and the average citizen's dream of free-wheeling down the open highway may well turn into a nightmare of dodging huge trucks on crowded freight-ways. For super-highways are bound to attract super-traffic in the form of super-trucks.

There is, of course, one practical alternative that public transportation authorities might well consider. But perhaps it's too obvious—like being unable to see the forest for the trees. That is, no way has yet been developed to match rail transportation in its ability to move great numbers of people and great quantities of goods rapidly and smoothly, both within crowded cities and over the countryside.

Knowing this is one of the reasons why I have confidence in the railroads' future. I take confidence, too, in the fact that, more and more, people seem finally to be realizing that all forms of transportation are interrelated—that you cannot subsidize and promote some without damaging the other. Perhaps it is not too much to hope that the day is not far away when the railroads will actually be allowed to compete with other carriers on an equal basis.

There is still another thing that inspires confidence in the future of railroading—that is, the immense progress we are making in developing new things to use in railroading. Research is going on within the industry at an unprecedented pace. Exciting changes have been forged and still more exciting changes are ahead of us.

On the basis of present progress, if you project your imagination into the future—to 1975, for instance—here are some of the things which you would probably see in railroad use:

Passenger cars are lighter and faster, fully cushioned against shocks. Locomotives, too, are lighter, with far greater horsepower in relation to weight. Freight cars include many specialized types, with one group carrying the bulk of intercity truck-trailers by rail.

Electronics provide the key to fast, safe train operation. Electronic signals are transmitted from the locomotive, with track receptors returning the signal to indicate the condition of track ahead and setting switches accordingly. Dispatchers direct train movements over many miles by setting switches and signals by remote control. In yards, whole freight trains are rapidly classified and switched by electronic machines which combine closed-circuit television and ingenious communications devices, and function on the basis of coded information.

With higher train speeds, track is built with better wear and riding qualities, and is kept free from even small irregularities. Track maintenance and replacement have become fully mechanized. Large projects are performed by huge machines which in one pass dismantle the track ahead and leave behind completely reworked track, ready for high-speed service.

In the field of management control, we find electronic "brains" receiving, evaluating and coordinating with lightning speed a great flow of facts from all over the railroad, feeding highly condensed reports to administrators by facsimile. Yesterday's performance thus becomes known to management today, and decisions and instructions become effective tomorrow. Past, present and future merge into one smooth flow of efficient performance based upon up-to-date knowledge.

While many of these devices and practices may seem somewhat in the dream stage, most are not at all hard to imagine. Some are already in service, in fact. Some are in use in other industries and need only to be adapted to railroading. Still others are undergoing advanced development.

Of course, this railroad of the future is not going to "just happen." It's up to you engineers to meet the challenge, constantly improving facilities and equipment and organization to make it happen. I'm certain that the railroads, if granted anything like an even break by public authority to compete for traffic, will make sure it does happen.

In the transportation race, the railroads are now three laps ahead of the next runner. In other words, railroads now handle three times as much intercity freight traffic as our nearest competitor. Still, all the others combined have almost evened the score—and we must remember that pressure is always on the front runner to maintain his lead. As railroad men, we must strive for constant improvement if we are to continue in the forefront of transportation. I, myself, have no doubt that we will.

President Miller: Thank you very much, Mr. May. You are indeed correct in saying that railroading presents a real challenge to those responsible for its welfare. I'm sure you may rest assured that this Association and the engineers here assembled will do everything possible to meet this challenge.

It is quite evident that the engineer today must not only take an interest in his own work, but must see what is going on about him, because all other industry is advancing very rapidly. They have their own research laboratories. We must know what they are doing. So it seems to me that the engineer must not only take an interest in his own work, but also take an interest in what is going on at the airport and on the highways, so that he will be in a position to meet further challenges which are being developed by these other modes of transportation.

As you have no doubt noticed from the program printed on your registration cards, there are several other important items to come before this opening session. I refer particularly to a discussion on the Railroads' Interest in Atomic Energy, also comments by Mr. Magee, director of engineering research, on the extensive research work being carried out for our committees.

I know that all of you will be highly interested in these two further features this morning, but before they are presented, I should like to interrupt our proceedings briefly to permit the Railway Age to take its usual convention photograph.

(Taking of convention photograph by Railway Age.)

President Miller: As we continue our morning session, I would like to excuse at this time those sitting at the speakers' table, with the thought that they will find it more comfortable and enjoyable to be seated in the audience during the remainder of the session. So you men at the two speakers' tables may retire to the audience.

Railroad Interest in Atomic Energy

President Miller: Since the next feature of our program deals with railroad interest in atomic energy—which is of interest to the mechanical departments of the railroads as well as to their engineering departments—we have been pleased to invite to the speakers' table a representative of the Mechanical Division, AAR, whom I should like to present to you. I refer to Mr. William M. Keller, executive vice chairman and director of research of the Mechanical Division. (Applause).

Will Mr. Magee please come to the platform?

No one knows the far-reaching effect that nuclear energy may have upon industry generally, and the railroads in particular, but I can assure you the railroads are determined to keep abreast of developments in this field, and alert to the possible applications of this new type of power to their various operations. Possibly the railroad man best informed on this subject is one of our own members, and a director of the Association, Ray McBrian, engineer of standards and research, Denver & Rio Grande Western Railroad, and a member of the AAR Committee on Atomic Energy. Accordingly, I shall now turn the meeting over to him.

Mr. Ray McBrian (D&RGW): Mr. President, members of the Association, ladies and gentlemen: Last year when I was approached about the possibility of presenting this subject to you, I met with Dr. Lawrence R. Hafstad, who was at that time director of the Reactor Division of the Atomic Energy Commission, and asked him to address our convention. Dr. Hafstad consented, and, in fact, was very desirous of being here to give, in an informal panel discussion, his views on what the railroads should be doing in their interest with respect to atomic energy. Before the first of the year Dr. Hafstad left the Atomic Energy Commission and became vice president in charge of the Nuclear Division of the Chase National Bank. Before we knew—and before he knew—what was happening, he was sent on a mission to India.

He called me on the phone and said that he regretted very much his inability to be here, but that he had selected as a substitute a speaker who had been associated with him on the Atomic Energy Commission. He referred to Col. Ralph L. Wassell of the Department of the Air Force, but said that since it would take a little time for clearance of this matter to come through, we couldn't make the official announcement prior to our convention. It is for this reason that our program reads "Railroad Interest in Atomic Energy" by myself. It wasn't until about a week ago that the Secretary of Defense finally approved Col. Wassell's appearance on our program. Col. Wassell is a graduate of the University of Oklahoma and of Stanford University, and is now assigned to the Industrial College of the armed forces. On finishing his present assignment, Col. Wassell will go back to the Atomic Energy Commission.

Dr. Hafstad told me that Col. Wassell, like he and I, had some very definite ideas as to the role the railroads should be playing in this field. In talking this over with Col. Wassell, it was agreed there would be no prepared paper, but that it would be strictly an informal discussion in which I would ask a few questions and he would give his views—his own personal thoughts.

It is, therefore, with great pleasure that I bring to you Col. Ralph L. Wassell, United States Air Force.

Col. Ralph L. Wassell: Thank you very much, Ray.

Mr. President, members of the Association, and guests: I am delighted to have the opportunity to be here and to participate with you in this meeting today. I am particularly gratified to see an organization of this sort, the AREA, representing the railroad industry. This group, meeting here today, symbolizes graphically to me the strength of the segment of United States industry represented by the railroad business.

Atomic energy is an extremely complex subject. It is an orphan child, really, born during the war-time condition of World War II that is now among us. Whether or not it remains an orphan, when looked at from the viewpoint of industry, depends on you people. Specifically—with regard to the railroad industry—what you people decide to do with it, whether you take it in and train it and utilize it, or whether after a look at and evaluation of it, you feel that it should go back to the orphanage, is your problem and your decision.

MR. McBRIAN: Col. Wassell, what do you feel the railroads can do to help develop their knowledge in the field of atomic energy?

Col. Wassell: Perhaps to get started on an informal discussion of the subject, the first thing I should do is to describe just what atomic energy is, in laymen's terms.

It can be looked at as a fuel, and as a new source of energy. That primarily is what it represents. However, as more is learned about it, I'm sure that in the broad field of scientific technology we will find many and diverse applications for the use of atomic energy other than just as fuel or energy to supply power.

I believe it has been said, at this meeting, that one takes the railroad industry almost for granted. I must admit that I probably have done so—the railroads are just there and I use them. But in considering the total national energy consumption of this country, the railroad industry uses about 8 percent of the total to play its part in creating our present gross national product. This alone is reason enough for the railroad industry to have a primary interest in what happens in the use of atomic energy.

I believe that the many by-product applications of atomic energy—its use other than as a fuel—will have sufficient impact in the future upon the entire economic structure of the country that the railroad industry will be well served to acquire a thorough knowledge of atomic energy so as to evaluate this impact in terms of the services the railroad industry may need to perform. For example, radiation-induced chemical reactions may well accelerate an already vigorous and rapidly growing petro-chemical industry, thus creating new processes, new products and new activities not now present in the economy which, in turn, may represent NEW railroad business. The overall pattern of United States energy consumption shows an extremely strong preference for liquid fuels. Atomic energy may well play a part in supplying the energy required to convert solid fuels (oil shales and coal) to a more preferable liquid form, thus affecting in a significant way the total quantity of available liquid fuels. This would be of economic significance to the railroad industry.

It seems to me that in tackling the job of getting started in this new field, each segment of industry must draw from within its own personnel resources. One of the fastest and most realistic ways of going about this is to take some of your own engineers —your mechanical, electrical, civil and chemical engineers—who have been with you just long enough to get a feel for railroad engineering problems, and send them to schools offering training in this new field. A leave of absence for a year or two on the part of promising individuals, sent to nuclear engineering courses at our universities would be a very good thing in developing your own know-how and your own ability to judge the merits of how useful atomic energy can be for your purposes.

MR. McBRIAN: Col. Wassell, is the technology of atomic energy far enough along that we should start its use immediately, or at least start our studies immediately?

Col. Wassell: If we look back, it is over 10 years now since the government first began vigorously exploiting the field of atomic energy, primarily for national security purposes. In so doing, a vast wealth of by-product information and knowledge has been gained in the basic science and technology which is essential to support any practical application for industrial use. In other words, the handbook information is being developed, and a large amount of it is already in existence.

One way to get a perspective of the status of the technology today would be to discuss for a moment the Atomic Energy Commission's 5-year reactor program that has been approved by the Joint Congressional Committee. This is a program to build experimental reactors over the next 5 years which will be sufficiently different in design features to cover a broad scope of possible designs that will convert atomic energy to heat so it can be used to generate power.

First of all, let's discuss for just a moment some of the fundamentals of the subject of atomic energy concerning the fission process.

We might describe the device designed to use atomic energy as being analogous to the fire box of a boiler or the combustion chamber of an engine. But in the case of atomic energy, the process of obtaining the available energy is the fission of fissionable fuel instead of the chemical combustion of powdered coal or oil. In the fission process, every time a fissionable atom is fissioned, it splits apart into two fission fragments (the atomic ashes) plus other radiation energy that is released. The energy released by this fission of the atom shows up in the form of kinetic energy of the two fission fragments. This kinetic energy is converted to heat immediately just by friction of the two fission fragments colliding with the atoms of material adjacent to them when the fission occurred. As a result of the fission process heat is generated just as in the case when combustion of coal or oil occurs.

The total energy in each fission is about 80 percent in the form of heat as just described and about 20 percent in the form of electromagnetic radiation. It is this latter characteristic of the energy released that presents the difficulty in handling a reactor as a practical machine or a practical fire box for, say, a turbine power plant or other type of application.

The nature of this radiation is such that it is harmful to life, and one must take measures in the design of a reactor machine to protect the personnel that will utilize it for whatever purpose it is designed.

MR. McBRIAN: Col. Wassell, I know you have given some thought to the possibility of the railroads' using this power. Would you mind giving us some of your personal ideas as you explained them to me, regarding what we might do, and the form of studies that might be made?

COL. WASSELL: Of course, there is the potential possibility of using the reactor, combined with turbines or conventional types of engine equipment, to provide direct motive power. There are even other ways in which the railroads might well consider these applications as they gain knowledge and judgment in this field.

I believe it was mentioned by a previous speaker here that it is reasonably realistic to look 5 to 7 years ahead, and that some people can look even further—10 to 15 years. It is in this latter realm that one must really look at the subject of atomic energy, because it is so new. I shudder to think of the total number of problems that must be solved before atomic energy can be added up in dollars and cents for its practical use in the business and economic sense.

The possibilities that have occurred to me in considering uses of atomic energy were really motivated by the interest that the electrical industry has displayed in this field. They are strong and active; when one hears the subject of atomic energy mentioned, he almost immediately thinks of the electrical field.

I am sure that in the future we will see the use of atomic reactors in plants for generating electric power.

During my studies in the Industrial College, when we were looking at the over all picture of military mobilization requirements and industry support of it, the thought occurred to me that the electric power distribution system could be duplicated or added to if the railroads were electrified and they sold excess electric power throughout the communities they now provide with transportation service. A study might be made of the long-range economic feasibility of this concept, utilizing atomic energy to generate the power.

The thought has also occurred that in such overhead tower structures as would be required for the transmission of power, there might be excellent space to rent or utilize directly for microwave communication systems. Therein you might have the possibility of renting space to the communications industry of the country. This would possibly result in a broadening of the network of power distribution and promote the general economic strength of the country. However, I would like to point out, again, that this is only a concept, and a study by your own people would have to be made to see if it made any sense at all.

MR. McBRIAN: Col. Wassell, isn't there also some possibility of microwave transmission of power that might conceivably come out of such a study?

Col. Wassell: Theoretically, I believe this might be possible—that one might eventually find a means for the transmission of power in this manner.

MR. McBRIAN: In closing, Colonel, could you give us the benefit of what you would do if you were in the railroad industry, in order to get started immediately?

Col. Wassell: It seems to me that you are in an excellent position through this very agency, this very Association, to initiate active work in a planned program of training, first among your young engineers who have promise. You might get them into schools and into association with such organizations as the Atomic Energy Forum, although, as I understand it, they are predominantly interested in the electric power industry's problems. Through this organization you might establish the equivalent of the Atomic Energy Forum if you choose. You could get on with the question of your own education in the subject itself, and proceed—if in the judgement of your engineers that it is desirable—into active participation in this entire field.

MR. McBRIAN: Isn't it true, Col. Wassell, that under the present Atomic Energy Act we can initiate study contracts?

Col. Wassell: Yes. In the 83rd Congress, last year, the Atomic Energy Act was amended for the simple purpose of facilitating a greater degree of participation by industry as a whole in the entire field of atomic energy.

We are still faced with the national security problem, and the weapons program, and the Atomic Energy Commission, as such, must consider this aspect of atomic energy. But at the same time it must, through the policy of the government, and as expressed by the President in his plan for the peaceful use of atomic energy, fully support and aid, where it can, the legitimate and direct interests of industry.

Mr. McBrian: Col. Wassell, this has been an excellent presentation of your personal views. I might mention, as I did to you, that beside the field of atomic energy for power, there is the unlimited field for the use of the by-product for inspections, for chemical reactions, and for work on fuels. These offer great possibiliites.

Thank you very much Colonel for your presentation to us.

Col. Wassell: Thanks very much, Ray. I can't overstress that the real way to approach this matter is for your own engineers to get into it and do it. (Applause)

President Miller: Thank you, Mr. McBrian and Col. Wassell, for a most interesting and challenging discussion of this important subject. We particularly appreciate your being here, Col. Wassell, and your important contribution to our program.

I am sure that the railroad field will not be found wanting when it comes to taking advantage of any new type of power, be it atomic or otherwise, which will improve the efficiency and economy of its various operations.

President Miller: At this time I would like to introduce to you three men who have just come into our room. When you go out to the Coliseum you will see a series of three flags around the balcony. You will find the Canadian flag, the United States' Stars and Stripes, and the Mexican flag. So it is a pleasure for me as your president, as a Canadian, to introduce to you three men from Mexico. I shall be glad to have them stand and be recognized.

One of them is Mr. Luis Moreno, assistant general manager, maintenance of way, National Railways of Mexico. (Applause). Another is Mr. J. E. Perez, chief engineer of the National Railways of Mexico. (Applause).

Now I am going to ask the third gentleman, Mr. Del Paso, if he would come to the microphone and say a brief word to our audience here on behalf of the railways and the supply industry in Mexico. I understand that Mr. Del Paso is what we call a supply man. We'll be glad to have a brief word from him.

Mr. Del Paso: Thank you very much. My friends from Mexico tell me to bring the greetings from all the Mexican engineers and the National Railways of Mexico, and we hope that all of you can visit us some time in our country. Thank you. (Applause).

President Miller: To supplement the details of the various research projects being conducted under the sponsorship of our committees, which will be brought out during the report presentations of these committees, we now want to give Mr. Magee, director of engineering research, AAR—under whose direction all of this research is being carried out—an opportunity to highlight the work of his staff during the past year, and to help us visualize the scope and character of the work planned for the year ahead.

Without further comment, I would like to introduce to you Mr. Magee, who will speak on Railroad Research Centers on New Horizons. Mr. Magee.

Railroad Research Centers on New Horizons*

By G. M. Magee

Director of Engineering Research, Engineering Division, AAR

There has never been a period in the history of railroading when research has been so actively and widely probing into new fields for improvement in railroad practices and techniques. Confronted with intensive competition, which is healthy, but hampered in meeting that competition by subsidization of competitors and almost strangulatory regulation, a challenge faces railroad management which calls for the marshalling of all available reserves. To that end railways and railway supply companies are now engaged in a tempo of research into new horizons that is truly amazing.

Railway revenues annually approach $10 billion. Railroading is one of the large private enterprises in the United States. Its product is a service. It is not in the manufacturing business, and this has an important bearing upon the respective fields of research of the railway industry and of the large number of industries that supply the railways with the materials and equipment they must have to provide this service of transportation to the public. For this reason we feel that it is our job to ascertain what our requirements are and to what extent they are being met in the light of what is available today. We depend upon the vast potentialty of research by the railway supply companies to

* This address was illustrated with colored slides.

develop and manufacture materials and equipment needed to meet these requirements. For this reason a true picture of research activity in the railway industry today must encompass not only what is done by the railways but also what is done by the railway supply companies, the latter being in effect by far the most important and significent share.

The Association of American Railroads is a voluntary association of railway companies formed to promote matters of common interest to all its railway members. One of the most important of these is the conduct of research. In order to meet this objective the first building of its Research Center was completed in March 1950 at a cost of $600,000. The site for this Research Center was selected on the campus of Illinois Institute of Technology in Chicago in its new Technology Center Development. A second building was completed in October 1954 at a cost of $400,000, and a third building is now being contemplated. It is envisioned that still two additional buildings will be required in the not too distant future.

The Research Center fulfills three important functions for the member roads of the Association. First, it conducts research as required by Association committees composed of railroad men to develop information needed for the establishment of recommended practices, specifications for materials, the design of component parts of track, structures, and rolling stock, and methods for packaging and loading. Second, it provides a specialized staff and equipment available to its member roads on an out-of-pocket cost basis to assist them in the solution of problems that may be peculiar to their individual railway. Third, it will upon request of member roads make an investigation of proprietary products offered for railway use and issue a factual performance report on the product to all member roads as information only, without any specific recommendation for or against the use of the product. It will be observed that this research plan of the Association is designed to encourage research on the part of supply companies by informing them of the requirements and recognizing the merits of their developments.

The responsibility for so-called acceptance testing to meet established specifications is left to the individual member road. In addition, many member roads conduct research in these own laboratories on matters in which they are particularly interested, and the Research Center serves as a medium for making the information so developed available to other member roads.

In general, facilities made available at the Research Center are of a type peculiar to the conditions of railroading and are not generally available in the research laboratories of universities or research foundations. These comprise testing machines designed to subject materials and component parts to the types of year, stress, shock and vibration that would actually be encountered in railway service conditions. Included in this category are rolling-load machines which can subject a full-size assembled rail joint to the same number of repetitions of loading and range of loading in a few weeks time that it would receive in track in a period of 15 to 30 years. This machine may also be used for testing of butt-welded joints for use in continuous welded rail. Other rolling-load machines are used for evaluating the performance of tie pads for preventing the cutting of ties by tie plates—one of the principal factors in shortening the life of treated hardwood ties. Another such machine is being used to determine the best techniques and procedures for building up battered rail ends by welding. Other similar rolling-load machines are used for evaluating the performance of new types of rail steel, such as heat-treated, flame-hardened, and various types of alloys. A Sonntag universal fatigue testing machine is available which is capable of subjecting materials to 2,000,000 cycles of stress within a period of only 24 hr. Another machine has been specially developed for testing under repeated loading the performance of fasteners for securing the sway bracing on timber trestles. A special burner oven has been developed for subjecting a specimen of creosote-treated wood covered with a fire retardant coating to the same intensity of temperature and duration that it would receive in a typical brush or tumbleweed fire. A procedure has also been developed for corroding specimens of steel on an accelerated basis with brine to compare the effectiveness of various inhibitors that might be added to the salt used in refrigerator cars for protecting against the damage done by the brine drippings to the underside of cars, and to rail, track and structures.

In the mechanical research laboratory special test equipment has been provided to certify various component parts used in freight cars in order that they may be freely used in interchange service between all member roads. These include a draft gear testing machine with a 27,000-lb tup which strikes hammer blows to simulate service shocks. The draft gear under test is seated on a special concrete caisson extending down 80 ft to bed rock. Other machines test couplers for pulling strength, and another subjects snubbers for freight cars to repeated loading to evaluate snubbing performance and wear resistance. Large fatigue testing machines are used for testing car axles. Another specially designed machine is being used to study the performance of greases in the various makes of roller bearings. Of special interest and value is a new journal bearing testing machine with which it is possible in the laboratory to subject any type of journal bearing, lubricant or waste to full journal bearing loads at speeds up to 100 mph with temperatures ranging from — 40 to + 150 deg, and in addition, subjected to alternate lateral forces and vertical impacts. A well-equipped machine shop is available at the Research Center for preparing test specimens and making necessary repairs to the various testing machine units. A giant squeeze test has been provided in which a full-size passenger car can be placed and subjected to an endwise compression between couplers of 1,000,000 lb to insure sufficient strength in the event of accidental collision. An impact test track has been provided, along with a 10-ton diesel unit, to reproduce typical switching impacts and study their effect on car construction and loading arrangements.

For studies of packaging at the Research Center complete facilities have been provided for constructing any type of wood box or crate, or any type of fiber-board carton. Testing machines are available in which it is possible to subject any package to typical compression, impact, vibration and tumbling, from which it is possible to evaluate the ability of the package to withstand a normal freight shipment. With this equipment it has been possible to assist many manufacturers in developing a more economical package for their products and one that is more likely to have its contents undamaged during shipment. Many of the tests by the Research Center staff are conducted on the track, bridges, or trains of member roads. To provide for this work the Research Center has acquired and maintains comprehensive and excellent equipment of the electrical type for measuring strains, impacts, vibrations, and pressures in any component of track and bridge structures or train equipment under actual service conditions up to maximum operating speeds. With this equipment research is continually under way to survey the present components of track and bridge structures and equipment and to develop practical means for improvements where required.

The above is a brief and general description of the Association's Research Center and its facilities, which has as its objective playing its part in advancing railway progress into new fields of development of equipment, plant, and operating procedures.

Now I would like to discuss some of the remarkable research developments of the railway supply companies. First, let me say that we can only touch on a few. Time available is one limitation. Another is that new developments are occurring so fast that it is impossible to keep up with them. I can only bring you, therefore, some of the more interesting and important ones that have come to my attention and within the scope that time permits. These are by no means all of them—there are many, many more.

Locomotives, the power that moves the trains, are always a subject of interest. Development through research of the diesel electric locomotive is now common knowledge. Today, because of this development, the steam locomotive is for all practical purposes a thing of the past. With only 100 diesel units in service in 1935, and 1000 in 1941, the total had mushroomed to 23,500 by mid-1954, at which time more than 85 percent of all train movements were being handled with diesel units. This rapid rise of the diesel locomotive to a dominating position in railway motive power is attributable to several inter-related factors. One is its high availability. Another is its high thermal efficiency, approximately 24 to 26 percent, or more than 4 times that of the conventional steam locomotive. Other advantages are its high starting effort and reduction of delays due to fuel, water and servicing.

Research into other types of motive power that may be still more advantageous is, however, underway. These include locomotives of the steam turbine type using coal for fuel. Other types being explored are the oil-fired gas turbine locomotives and the coal-fired gas turbine locomotives. The gas turbine for the locomotive is the same in principle as that for the jet plane, except that in the locomotive the exhaust gases are used to drive a turbine for producing electricity for the traction motors, whereas in the jet plane the exhaust gases discharge freely into the atmosphere to produce propulsion. Another interesting development is the Ignitron electric locomotive which utilizes a mercury-arc vacuum tube to convert alternating current, which has transmission advantages, into direct current, which has service advantages. This same Ignitron rectifier is being utilized in so called MU or multiple unit cars for commuter service. Looking still farther into the future, there is the atomic-powered locomotive. At the present time intensive research is underway using various types of reactors to develop the most suitable type of equipment for release of this available energy. Although at the present time none of the railways, and so far as I know, none of the railway supply companies are specifically engaged in the construction of an atomic-powered locomotive, nevertheless, the development of atomic power is being closely followed by both interests, and the construction of an atomic-powered locomotive will no doubt be undertaken at the appropriate time. It may well be that atomic power will be used at fixed plants for generating electrical power which will be transmitted by power lines to electric locomotives of the Ignitron rectifier type.

Wonderful progress has been made in passenger equipment. This is evidenced by the modern, lightweight, air-conditioned, attractively decorated and fixtured coaches, dining cars, and sleeping cars now in service, including the Vista Dome. At the present time, however, there is great interest in still further developments, particularly along the line of the Talgo-type train. Outstanding advantages of this type of equipment are its light weight and low center of gravity, combined with utilization of the guided axle to permit exceptionally high speed on curves with safety and passenger comfort. The train of this type provides commodious passenger accommodations at a weight of 500 to 600 lb per seat compared to a weight of 1600 to more than 2000 lb per seat for modern type cars now in general use. Important drawbacks to the general adoption of such cars are their lack of interchangeability with conventional units and the difficulties with their low floors in many stations, principally in the East where station platforms are at the same height as the passenger car floor height—the floor height of the Talgo unit being 33 in lower than that of a standard coach.

Another development of interest to passengers is new ticket selling facilities, one of these being in the 30th Street Station of the Pennsylvania Railroad at Philadelphia. An electrically lighted board is visible to the prospective passenger, and on this board is shown up to the minute the available space accommodations on each train for a week ahead. For example, if the purchaser desires to go to Chicago, he can glance up at the board and immediately note just what type of pullman accommodations are remaining and available for his use. Purchases are immediately posted on the board so there is no duplication of space selling.

Tickets are printed in a matter of seconds in a Ticketeer. Queries for rate and route information are answered quickly by a clerk at a microfilm reader. In the years to come assignment of space at intermediate stations could become a thing of the past, with all reservations made from a central point. A request for space from any intermediate point would take only seconds by high-speed facsimile transmission.

A development of interest in connection with freight cars is a new paint-stripping set-up on the Norfolk and Western Railway at Portsmouth, Ohio. A so-called stripping tunnel is provided into which the car is placed, and its surface is completely covered by means of nozzle sprays with a hot alkaline stripping solution. Then the car is moved from the tunnel into a water spray which rinses the entire car surface. Following this, the surface is sprayed with phosphatizing solution, and as soon as this drys the car is ready for painting. It is possible with this equipment to prepare 20 cars for painting within a period of 8 hr at about one-third the cost of sandblasting and without the other disadvantages attendant upon the use of sandblasting.

So-called piggy back or the operation of truck trailers on flat cars is not a new development by any means, as it was first initiated in 1926. However, it has had a new birth, and at the present time there is great interest and many new developments underway in piggy-back operation. Special types of flat cars are being designed and constructed for this use. On March 3 the Pennsylvania inaugurated a full-train piggy-back service each way daily between Chicago and New York which they have termed their Truc-Train service.

Several different methods are being tried for the transfer of the track trailer to the flat car. In one method, the flat cars are pushed into a stub track with a ramp at the end. The trailers are then backed onto the string of flat cars. In another method the trailers are equipped with dolleys and the flat cars with center rails, so the trailer weight is lifted off the tires, and the trailer is guided into position by the dolley wheels and car rails. In another method, the trailer is lifted bodily and set on the flat car by a large lift truck. Piggy back offers two advantages: first, a more efficient utilization of manpower, and second, relief to highway traffic from the large truck trailers.

With respect to railway track, there are two noteworthy developments. Here again one of these is the rebirth of an idea that is by no means new, and that is the use of continuous welded rail. Continuous welded rail was first used on the Delaware and Hudson more than 20 years ago, but its use did not progress because of concern over safety, the high cost of the weld, and the belief that expensive track fastenings were required. Since that time experience has demonstrated the safety of the track. It has been found that conventional type fastenings can be used satisfactorily, and the cost of the weld has been reduced and its quality improved. Because of the very substantial savings in the cost of maintaining and surfacing rail joints that experience has shown to be obtainable with continuous welded rail, it appears that its use is going to become markedly increased in the coming years. The type of weld used is a butt pressure weld with rail ends being brought up to a forging heat by the use of acetylene gas or electric flash resistance.

The second noteworthy advance in track procedures is the marvelous development in maintenance-of-way work equipment. Equipment of this type has been used to a limited extent for many years, but the increase in track labor wages since World War II has provided the emphasis for the development of equipment for almost every track maintenance task. As a result we have today machines for complete reworking of the ballast. The ballast between ties and in the shoulder can be loosened by a scarifier to kill vegetation and promote drainage. It can be removed from the cribs entirely and wasted, or picked up along with the ballast in the shoulder, cleaned on shaker screens, and replaced in track. Machines have even been developed to lift up the track and clean the ballast under the ties. New ballast is evenly distributed by machines prior to raising the track and tamping.

Renewing over 30 million cross ties a year is one of the big maintenance jobs. Machines have been developed for pulling the track spikes. Other machines lift the rail, facilitating tie removal. The ties can even be pulled out of the track by machine, and the new ties can be pulled into position by machine. Machines are also available for driving the spikes into the new tie after it has been placed in track.

Large man-hour savings are being effected with multiple-unit tampers. Formerly, in tamping ballast, one operator was required for each tamping tool. But today machines are available so one man can operate all of the tampers simultaneously for completely tamping one tie. These machines may use pneumatic tamping tools or electrically or mechanically operated tamping tools. Smaller and more mobile units are available for tamping one end of the tie. And after the track is surfaced and tamped, it can even be lined by machine. Other machines available and used include rail cranes, tie adzers, power wrenches and drills, rail saws, rail-end hardeners, chemical weed sprayers, weed burners, all types of earth moving machines, and many others.

A most remarkable development has been effected in car-retarder operation. Several railroad hump yards have now been equipped with electronic devices for accurately controling movement of the car after it is cut off at the hump. For example, the car foreman needs only to push a button to designate the track into which the car or cut of cars is to go. As the car rolls down the incline, just before it reaches the first car retarder the wheel load is determined and, by radar, the speed at which the car is moving. As it approaches the next retarder the speed is again determined and, indicative of its rolling resistance, the change in speed is fed into an electronic discriminator into which is added a resistance corresponding to the distance to which the car will have to go into its consigned track. Thereupon the discriminator determines the speed at which the car should leave the retarder and by means of radar control retards the car to that exact speed. Thus, the classification of cars is insured with minimum damage to lading from the shock of switching impacts.

Many developments are underway utilizing electronic devices to facilitate railway operation and accounting procedures. Centralized traffic control is expediting train movement and in many cases permitting consolidation of main tracks, with attendant savings in maintenance cost and taxes. The Pennsylvania has a new train performance calculator which makes quick work of figuring out how any train will perform on any given stretch of track. Tonnage and time problems that formerly took five days to solve are now solved in one.

All types of electronic devices are being developed to expedite and reduce the cost of accounting work. A computor using transistors in place of vacuum tubes is being tried out, producing the advantages of reduction in size and power requirements. An example of new electronic devices is the automatic payroll machines on the Chicago and North

Western Railway, which prepare 30,000 pay checks twice monthly. First, a punch card is prepared. From then on, each check is automatically computed, printed, endorsed, and stacked in name order.

As previously stated, the foregoing are only a few of the many technological advances that the vast research potential of railway supply companies has developed or is developing. They serve only to give some idea of the extent of railway progress through research —progress which assures this nation that it will have in the future, as it has had in the past, the finest railway transportation system in all of the world.

President Miller: Thank you, Mr. Magee. We appreciate your review of our research work, and the interesting details which you have brought to our attention in your illustrations.

May I take this opportunity to express to you and your staff, on behalf of our Association, our appreciation of your diligent and productive efforts in our behalf.

Now, before we adjourn this morning, I should like to make a few important announcements.

One of these has to do with a last-minute addition to our program tomorrow morning, in the form of a 25-min color motion picture of highly mechanized tie renewal and surfacing operations on the Southern Railway. I know that you will be intensely interested in seeing this picture, because of the new attitude which it depicts, with no limitation on ideas or ingenuity to bring about production-line methods, and minimum costs to track maintenance operations. The showing of this film will begin at 11:30 am tomorrow, in the Red Lacquer Room.

Immediately following the picture we will all go to the Annual Luncheon in this room.

(Announcements on committee luncheons and Annual Luncheon.)

President Miller: Our afternoon session today will include a number of interesting reports and addresses, and I call your attention particularly to the address to be made in connection with the presentation of Committee 25—Waterways and Harbors, by Mr. Paul F. Royster, Assistant to the Undersecretary of Commerce for Transportation, on "Fair Play in Navigational Clearances for Bridges," and urge as many of you as possible to be here.

The meeting now stands recessed, and will reconvene in this room at 2 o'clock this afternoon.

(The meeting recessed at 12 o'clock noon.)

Afternoon Session—March 15, 1955

(The meeting reconvened at 2:05 o'clock, President Miller presiding.)

President Miller: Will the meeting please come to order? The first report on our program is that of Committee 14—Yards and Terminals, of which J. N. Todd, superintendent of scales and work equipment, Southern Railway System, is chairman. Will Mr. Todd and members of his committee please come to the platform and present their report?

Under the seating arrangement planned in connection with our two speakers' tables, may I ask that the chairman, vice chairman, secretary, and all subcommittee chairmen take their places at the high-level speakers' table. All other members of the committee are asked to find their places at the lower table, and then fill out such vacant seats as are available at the top table.

Before presenting the chairman of this committee to you, I want to invite your comments and criticisms in connection with the presentation of each and every report, to the extent that time will permit, and I would point out that a limited amount of time has been provided each committee for this purpose. While it is expected that most questions with respect to committee reports have been raised and answered in committee deliberations, further questions, comments and criticism will be welcome from the floor. This applies to information and progress reports as well as those dealing with Manual recommendations, looking to the development of any kind of supplementary information that will make these reports more valuable to our members as printed in the Proceedings.

Portable radio microphones have been provided for our use through the courtesy of the Motorola Company, and will be made readily available to you by one of the hotel bellmen operating in the different aisles. All you need to do is to stand at your place (and I would suggest that you raise your hand) and the bellmen will deliver one of these portable microphones to you.

I will demonstrate just how this works. It is very similar to a dispatcher's telephone, in that there is a button on the left-hand side. Hold the microphone about a half inch from your mouth, press the button when you talk, and when you are through talking, just release the button.

We have five or six of these microphones available, and I am sure you will be able to use them. All you need do is to stand, raise your hand, and the bellmen will be glad to deliver them to you. Before speaking on your subject, kindly give your name and the name of your railroad, for the information of our reporter.

Discussion on Yards and Terminals

(For report, see pp. 393–423.)

(President G. W. Miller presiding.)

Chairman J. N. Todd (Southern): Mr. President, Committee 14 will present five subcommittee reports and a special talk with slides on the behavior of roller-bearing cars in a gravity yard. Our reports are found in Bulletin 518, beginning on page 393. We hope there will be questions from the floor, and opportunity for that purpose will be provided.

Our first report is on Scales Used in Railway Service, and includes principally a new specification for large-capacity motor truck scales, which should lie over for a year before adoption. We will also give you a report, not printed in the Bulletin, on the latest developments in electronic scales in railway service. The report will be presented by C. L. Richard, retired weight engineer, U. S. Department of Agriculture, chairman of the subcommittee.

Assignment 3—Scales Used in Railway Service, was presented by C. L. Richard (U. S. Department of Agriculture).

Mr. Richard: Mr. President, your committee presents as information a report on Specifications for the Manufacture and Installation of Four-Section Motor Truck Scales, and plans to recommend that the material be published in the Manual next year.

These specifications were prepared pursuant to authority granted by the Board of Direction, after it was advised that there was available no standard code of engineering specifications upon which the purchase of four-section motor truck scales could be based. Since this Association—by virtue of its past reports and specifications relating to large-capacity scales—is recognized as being the authoritative source of such information and reference material, it is believed that adoption of specifications and their publication in the Manual is desirable.

Your committee prepared these specifications without soliciting the collaboration of the Association's Committee on Iron and Steel Structures. However, it is suggested that the latter committee be invited to review the specifications before they are published in the Manual, so that the specified structural steel requirements will be in accord with those of the Association.

President Miller: Thank you, Mr. Richard.

You will note, gentlemen, that this is a tentative specification, which should be reviewed by you during the following year, so that we can consider it at our next convention for inclusion in the Manual.

Your report, Mr. Richard, will be received as information.

Mr. Richard: Your committee has submitted no formal progress report on electronic scales for weighing freight cars, but offers the following as a summary of current information, and requests that the subject be continued.

Some 30 railway track scales of the electronic load cell type have now been installed in the United States and Canada. They represent the products of three individual manufacturers. Approximately 20 of these scales are in use at steel mills, chemical plants, coal or ore mines, and other establishments of heavy industry. With one exception, they are of conventional length, and are employed for weighing cars at rest—the weight of empty or loaded cars being recorded by push-button.

The remaining scales, installed in railway yards, consist of one flat yard installation and nine hump scales, all designed for weighing cars in motion with automatic recording of weight. They range in length from 65 to 105 ft, and have gradients up to 5 percent.

Although information made available to your committee by manufacturers and users of electronic-type track scales does not permit conclusive statements regarding the comparative merits of electronic track scales and conventional track scales, the following is submitted as the committee's present appraisal of indicated potentials.

First, for weighing cars at rest, in industry or railway flat yards, electronic track scales may be installed for the same costs, substantially, as the conventional lever type. They have about the same accuracy characteristics, require generally the same amount of maintenance attention, and have the advantage of providing more rapid weight determination with automatically recorded weight values in printed form, and indication or recording of weight at remote locations if required. They may also be installed in some locations where lever-type scales would be impractical.

Second, for weighing cars in motion, particularly in hump yards, where the trend is toward greater scale length and increased gradient, there are indications that installation costs may favor the electronic type because of lower excavation, concrete and steel costs. Accuracy of weighing and speed of operation compare favorably with that of conventional scales equipped with mechanical weight recorders, but the electronic type offers the advantage of providing printed weight records in digital form and in remote locations.

Your committee requests permission to continue its study of the subject, with a view to collecting and analyzing data upon which may be prepared future reports of more conclusive character.

Chairman Todd: Are there any questions, or will there be any discussion? We have the experts here—you're free to ask questions.

Our next report is on Waterfront Terminals, with special reference to ore piers on the Atlantic seaboard. In the absence of our subcommittee chairman, Mr. Harman, the report will be presented by Mr. B. G. Packard, office engineer of the Chicago and North Western Railway, a very capable member of the subcommittee.

Assignment 4—Waterfront Terminals, was presented by B. G. Packard (Chicago and North Western) in the absence of subcommittee chairman L. C. Harman (Chesapeake & Ohio).

MR. PACKARD: Mr. President, members: Waterfront terminals present many and varied problems. It is impossible to prepare a single report covering the various aspects of this subject.

A year ago this subcommittee, in a progress report, confined its study to the general aspects of the subject. Our present report deals with ore piers on the Atlantic seaboard, describing the general layout of the piers, unloading facilities and track arrangements.

The pier dimensions depend on the number of boats which will be tied up alongside, and the trackage thereon for taking the cars away from the piers. The unloading facilities are highly mechanized, with traveling cranes and endless belts.

Track arrangements must suit the locale, both as to grades and as to plan, and must be able to handle loads and empties to and from the pier in order to maintain the uninterrupted loading of the vessels.

It is recommended that the subject be continued so that we will be able to report next year on banana piers at harbors on the Gulf coast.

CHAIRMAN TODD: Will there be any questions on this report? Thank you, Mr. Packard.

Our next report is the second in a series of reports on handling LCL freight by conveyors. The chairman of the subcommittee who will present the report is F. E. Austerman, assistant chief engineer of the Chicago Union Station Company.

Assignment 5—Study of the Handling of LCL Freight by Conveyors, was presented by Subcommittee Chairman F. E. Austerman (Chicago Union Station Company).

MR. AUSTERMAN: Mr. President, many railroads are replacing their multi-story freight houses in the congested areas of our large cities with single-story freight houses. These large single-story freight houses are more adaptable to the mechanical handling of freight on trailers. This report covers the transportation of trailers by mechanical means instead of by gasoline or electric tractors. Both the in-floor and the overhead towing conveyors are described in this report, with the distinct advantages of each. I am sure that your railroad will find many advantages and economies in the installation of towing conveyors.

I want to thank the secretary's office for the excellent reproduction of the pictures of towing conveyors in the Santa Fe and Burlington freight houses in Chicago.

This is a final report, submitted as information, but a brief report will be submitted for inclusion in the Manual next year. I recommend that this subject be discontinued.

PRESIDENT MILLER: Thank you, Mr. Austerman. Your report will be received as information.

CHAIRMAN TODD: Will there be any questions on Mr. Austerman's report?

Thank you, Mr. Austerman.

Our next report is on a subject recently assigned—Facilities for Loading and Unloading Highway Semi-Trailers on Railroad Cars—and is one of considerable interest at this time. Only within the last few days or weeks, announcements have been made about regular service by railroads handling semi-trailers.

The chairman of the subcommittee, Mr. C. F. Parvin, as absent, and the report will be presented by J. C. Warren, division engineer of the Pennsylvania Railroad.

Assignment 6—Facilities for Loading and Unloading Highway Semi-Trailers on Railroad Cars, was presented by J. C. Warren (Pennsylvania) in the absence of Subcommittee Chairman C. F. Parvin (Pennsylvania).

Mr. Warren: Mr. President and members: This is the first report on an assignment new to this committee. It is submitted as information, with the recommendation that the subject be continued.

Recent expansion of this means of transporting freight makes the subject one of interest to study, and we are sure it will be of increasing interest to the members of this Association.

It is too soon to predict the extent to which this type of business will develop. However, since our last convention, additional railroads have started the movement of highway semi-trailers on railway cars. The number of semi-trailers and railroad cars handled will determine not only the size of facilities needed, but may well determine the type of facility to be required.

This report outlines certain general conditions that apply to any method that may be used, and then describes three ways of loading and unloading highway semi-trailers on railway cars. Following this description of each way, there are given the advantages and disadvantages of each, respectively.

Having in mind the thought that a railroad may find it desirable to change the type of facilities with the growth of this traffic, the committee has refrained from recommending any one way of loading or unloading highway semi-trailers on flat cars. This first report will serve as a guide to those making studies for their first installation, or the enlargement of present facilities.

Mr. President, I recommend this report be received as information, and that the subject be continued.

President Miller: Mr. Warren, your report will be so received.

Chairman Todd: Are there any questions?

Our last subject is also a new one, and one that is timely and up to date—Electronic Devices in Yards and Terminals. In its preparation we have collaborated with the Communications and Electrical Sections, AAR. The report will be presented by R. F. Beck, assistant engineer, Elgin, Joliet & Eastern Railway, chairman of the subcommittee.

Assignment 7—Electronic Devices in Yards and Terminals, was presented by Subcommittee Chairman R. F. Beck (Elgin, Joliet & Eastern).

Mr. Beck: Mr. President and members: Important advances have been made within recent years in the application and use of electronic devices which have contributed immeasurably to the increased efficiency of our freight terminals. These devices have greatly expedited traffic through terminals, provided increasingly better car reports and accounting procedures, and promoted over-all safety.

The many uses to which electronic devices have been adapted are covered in this report. Included are paging and talk-back speakers; intercom systems; base, mobile and portable radio; signals; electronic scales; car reporting systems; television; automatic switching; and automatic retardation.

Various devices have been developed for retarder yard operation which assist the retarder operator to control the speed of cars moving by gravity to the classification yards, thus providing the maximum operating capacity with minimum damage to cars and lading.

In several yards an electronic speed indicator shows the retarder operator the speed of cars as they move down the hump. In other yards the speeds at which cars are released from retarders are pre-selected by the retarder operator. One of the most recent developments in this field has been the installation of automatic retardation. In other words, automation, that magic word we have been reading so much about, has now been placed in operation on American railroads. This system measures the rolling resistance of cars as they move down the hump. Automatically, releasing speeds from retarders are selected which permit cars to arrive at tangent track at safe coupling speeds.

This is a final report, submitted as information, with the recommendation that the subject be discontinued.

President Miller: Thank you, Mr. Beck; your report will be received as information.

Chairman Todd: Are there any questions on this final report on electronics in yards and terminals?

That is all the regular work of the committee, Mr. President. We are fortunate in being able to sponsor a talk with slides on the behavior of roller-bearing cars in a gravity yard. The one responsible for the planning was our member, Mr. N. C. L. Brown of the General Railway Signal Company. The location is Seven Islands, Quebec, but more details will come from our speaker, another member of AREA and one who is well qualified, Mr. A. V. Dasburg, also of the General Railway Signal Company. It is a pleasure to present Mr. Dasburg.

Handling Roller-Bearing Cars by Gravity

By A. V. Dasburg

Transportation Research Engineer, General Railway Signal Company

Introduction

Within recent years there has been a trend toward greater use of roller-bearing-equipped freight cars. Generally, these cars have been built for a special service, and their operation has been limited to the lines of the owning road. However, increasing numbers are now being found on lines and in yards where they previously have not been handled. This trend has led to such questions as these:

1. How does the performance of roller-bearing cars differ from those having the conventional solid bearings?
2. Must special precautions be taken in humping roller-bearing cars in existing yards?
3. Should roller-bearing cars be considered in the design of grades for new yards?

This brief discussion will approach these questions by reporting the experience of one railroad which operates a single type of roller-bearing car. Admittedly, it is an idealized approach, yet one which may serve as a guide to the more complex problem of handling mixed traffic in gravity yards. Furthermore, the hope is that others will be stimulated to contribute their findings to the data available on this subject.

Description of Tests

The rolling resistance tests described herein were made at the ore loading and stockpiling facility installed by The Iron Ore Company of Canada at Seven Islands, Que.

Fig. 1 is an aerial view of the terminal, showing four of the Seven Islands in the

Fig. 1.

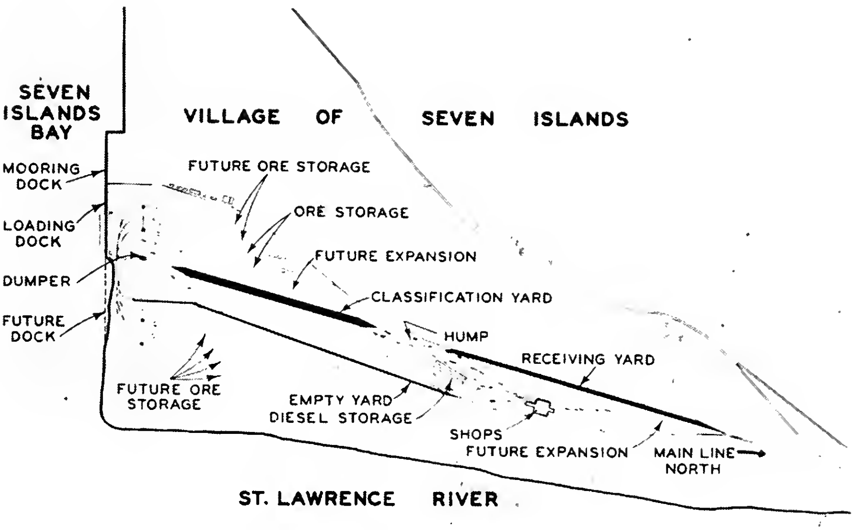

SEVEN ISLANDS BAY
VILLAGE OF SEVEN ISLANDS
MOORING DOCK
LOADING DOCK
DUMPER
FUTURE DOCK
FUTURE ORE STORAGE
ORE STORAGE
FUTURE EXPANSION
CLASSIFICATION YARD
HUMP
RECEIVING YARD
FUTURE ORE STORAGE
EMPTY YARD
DIESEL STORAGE
SHOPS
FUTURE EXPANSION
MAIN LINE NORTH
ST. LAWRENCE RIVER

Fig. 2.

distance. The light area extending diagonally across the picture is formed by the receiving, classification and empty yards, with the loading docks in the upper right hand corner.

Fig. 2 shows schematically the relative location of the major elements at the terminal. The receiving yard is in the lower right hand corner. Next to it is the hump, followed by the classification yard to the left. On the extreme left is the car dumper, which is connected to the empty yard by the semi-circular track. The dark areas in the receiving, classification and empty yards indicate existing trackage and the lighter areas future expansion.

All loaded cars enter the classification yard in single car cuts because they are weighed in motion.

The dumper is designed to handle single or two-car cuts with a cycle time of 1 min. Two-car cuts are used to load ore boats and single cars to stockpile ore, since there is now only one ore stacker. A second stacker will be added in the future, and this will permit two-car dumping for the stockpiles.

To reproduce actual operating conditions it was decided to test a single car with maximum load, a single empty car, and an empty two-car cut.

Fig. 3 shows cars for this service built by the Pullman–Standard Car Manufacturing Company. Designed to carry a load of 95 tons, their tare weight is approximately 27.3 tons. They are equipped with ASA ride control trucks, Timken roller bearings, and two clasp brakes per wheel.

Tests, conducted in June and November 1953 and May 1954 for the purpose of establishing final grades in the classification and empty yards, did not involve special precautions to produce minimum rolling resistance conditions. Rails and car trucks were relatively new and free of wear. Equipment furnished by the Timken Roller Bearing Company used the method of recording wheel revolutions per second to determine velocity.

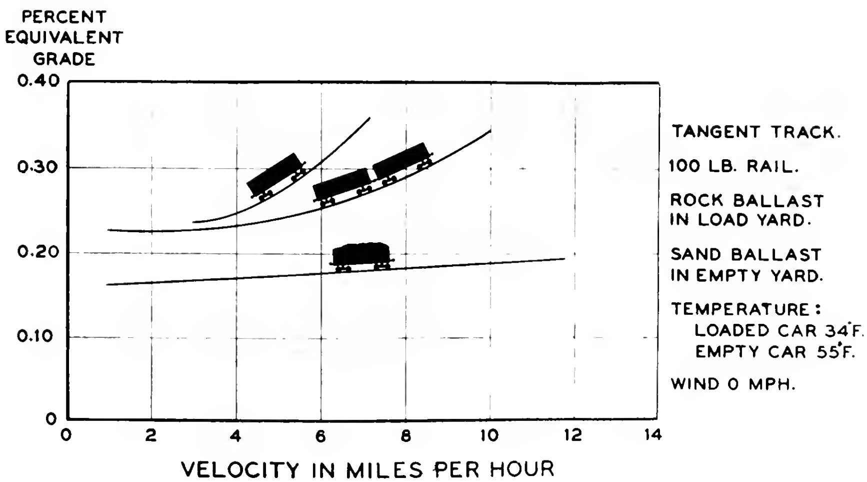
Comparative rollability of empty and loaded cars is shown in Fig. 4, where rolling resistance in equivalent grade is plotted against velocity in miles per hour. The lower curve represents the fully loaded ore car on tangent track in the classification yard. The average resistance is approximately 0.175 per cent at 4 mph, and there is a slight increase with speed. The middle curve is for the empty two-car cut. Its average resistance is approximately 0.235 per cent at 4 mph and rises to 0.345 per cent at 10 mph. The single empty car is shown in the upper curve. Its average resistance is approximately 0.25 per cent at 4 mph, rising to 0.35 per cent at 7 mph. The two curves for empty cars represent the performance on tangent track in the empty yard.

Fig. 5 shows the estimated curve resistance for a 19.0-deg curve with 88.5 deg of central angle located between the dumper and the empty yard. Track gage through the curve is 4 ft 9 in. The outer rail was greased.

Estimated resistance of the loaded car at an average speed of 10.50 mph is 0.0118 ft per deg of central angle. The value for an empty two-car cut at an average speed of 10.58 mph is 0.0138 ft per deg. The value for a single empty car at an average speed of 7.87 mph is 0.0145 ft per deg.

Fig. 6 is a plot of the installed profile for the hump lead and classification tracks. The elevation difference between the hump crest and the end of the group retarder is 6.75 ft. The grade from the group retarder to tangent track at station 44 averages —0.175 per cent, and it is —0.125 per cent from this point to station 30. Finally, there is a —0.05 per cent grade between station 30 and station 15. These grades permit handling cars to the far end of the yard or to near end clearance without requiring a wide variation in leaving speeds at the group retarder.

Fig. 3.



ROLLING RESISTANCE OF ROLLER BEARING ORE CARS
IRON ORE COMPANY OF CANADA

Fig. 4.

ESTIMATED CURVE RESISTANCE OF ROLLER BEARING ORE CARS
IRON ORE COMPANY OF CANADA

19° CURVE. 88.50° CENTRAL ANGLE.
TRACK GAUGE 4 FT. 9 IN. 100 LB. RAIL.
OUTSIDE RAIL GREASED. TEMPERATURE 34-55°F.

DESCRIPTION	WEIGHT IN LBS.	AVERAGE VELOCITY MPH.	AVERAGE CURVE RESISTANCE FT. PER DEGREE
SINGLE LOAD	251,150	10.50	0.0118
TWO EMPTIES	109,200	10.58	0.0138
SINGLE EMPTY	54,600	7.87	0.0145

Fig. 5.

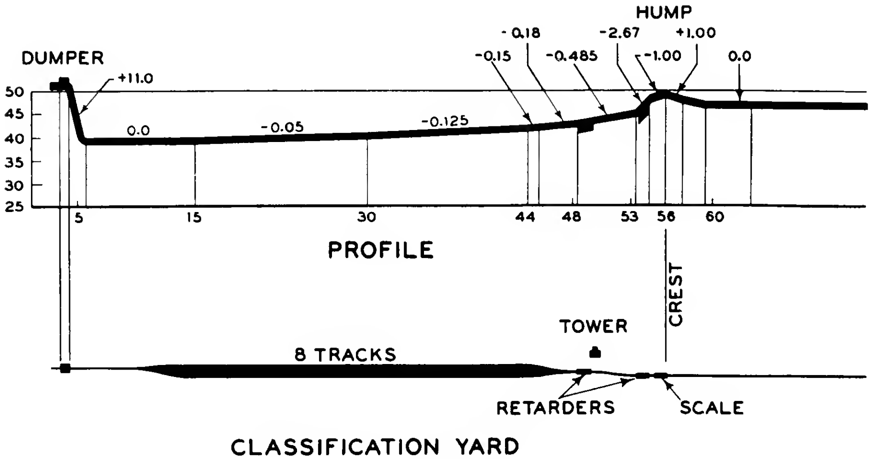


Fig. 6.

Fig. 7 is a plot of the installed profile for the empty yard. The elevation difference between the dumper and the end of the retarder is 12 ft. The grade from the retarder at station 19 to tangent track at station 25 is —0.275 per cent. Between station 25 and station 55 it is —0.25 percent, and from station 55 to 65 it drops off to —0.23 per cent. These grades ensure that under average conditions both single and double cuts will reach station 65. Thus, 125-car trains can be built up on a single track. In actual practice cars will overtake each other and drift down in groups until stopped by the plus grade at station 67. A head wind will tend to gather cars into groups even before they reach the body tracks. However, unless it is severe they eventually drift on down to the end. Strong tail winds will cause the cars to accelerate. Under such conditions they are released from the retarder at minimum speed to avoid excessive coupling speeds.

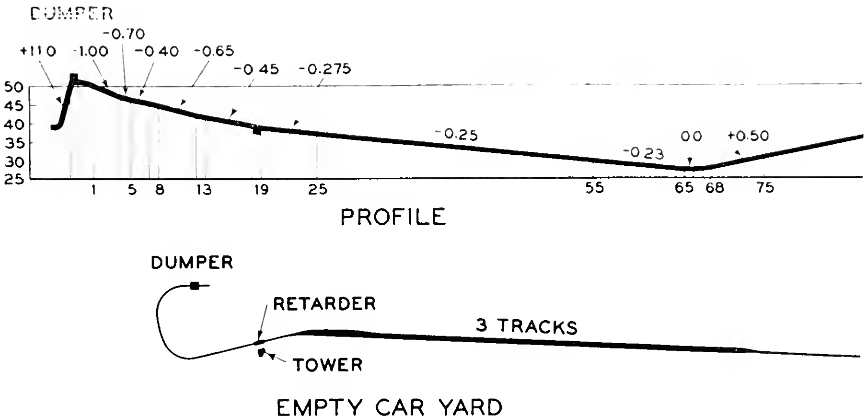


Fig. 7.

These results are entirely valid only for the particular yards and conditions under which the tests were made. Variations may arise, depending upon local conditions. However, there was an opportunity to check the performance of a single ore car with a light load in St. Luc Yard on the Canadian Pacific. Its resistance was found to be 0.26 per cent at a speed of 3 mph, which is close to the values obtained at Seven Islands.

The increase in rolling resistance with velocity for the empty cars suggests that penetration of a yard can be obtained most efficiently by extending the grade rather than by releasing cars at high speed. This fact influenced the final choice of grades in the empty yard at Seven Islands.

The difference in resistance for loaded and empty cars illustrates the difficulty in selecting a body track grade which would be suitable for both, particularly in a yard where the body tracks are long.

Conclusions

Rolling resistance values obtained in the tests are within the range which will be encountered with solid-bearing cars.

The lowest reported resistance for a loaded roller-bearing car is 0.075 per cent. This is the breakaway value for a 70-ton gondola as measured at Altoona, Pa., with brake shoe drag eliminated.

The rolling resistance of well maintained loaded solid-bearing cars has been measured to be as low as 0.08 per cent.

Therefore, it is reasonable to assume that the performance of the best solid-bearing cars and those having roller bearings will be similar.

The significant differences are that roller-bearing cars have a very low starting resistance and a high degree of uniformity in rolling resistance. Under equivalent conditions the solid-bearing cars will have a high starting resistance and may have a wide range in rolling resistance.

Returning to the three questions which were raised at the beginning of this discussion, the following partial answers are suggested:

1. The behavior of roller-bearing cars is fundamentally the same as solid-bearing cars, except for their low starting friction and greater uniformity. Therefore,

while in motion, both types can and should be handled in the same manner. However, the easy starting characteristic of roller-bearing cars may create a problem of possible rollback caused by wind or a reverse grade in the profile.

2. Roller-bearing cars can be handled in the same manner as solid-bearing cars in existing yards if the yard grades have been designed for easy running solid-bearing cars. When the grades are such that roller-bearing cars accelerate, some solid-bearing cars also will accelerate. Here the question of numbers plays a part. The acceleration of a few cars may be overlooked whereas many accelerating cars of either type can create a definite problem.

3. Roller bearing cars should be considered in designing the grades for new yards. If the yard is to handle only this type, the grades can be tailored to the operation as was done in the case of The Iron Ore Company of Canada.

   When roller-bearing cars are to be mixed with solid-bearing cars, they should be treated in the same manner as easy running solid-bearing cars with respect to body track grades. If the yard is to be bowl shaped, the percent and amount of plus grade as well as the location of skates should take into consideration the low starting friction of the roller-bearing cars.

The choice of grades in a gravity yard is always a matter of compromise between safe coupling speeds, the range of rolling resistances to be handled, and the distance cars are to run. In the early days it was reasoned that the average car should be driven well into the yard. Body track grades were selected to accomplish this with the knowledge that some cars would accelerate sufficiently to cause damaging impacts.

There are now more solid-bearing cars which are easy running, and greater attention is being given to the question of lading damage. Therefore, the trend recently has been toward lighter grades through the body tracks. This means that the easy running cars are less likely to accelerate, while at the same time the hard running cars will stop sooner.

Summarizing, it seems fair to state that roller-bearing cars present no greater problem in gravity yards than the best solid-bearing cars. Both must be considered in planning yard grades if optimum performance is to be achieved.

In closing, I wish to express my appreciation to P. C. Paterson, service manager, Railway Division, Timken Roller Bearing Company, and N. D. Vernon, engineer, Iron Ore Company of Canada for making available the test data and profiles used in the preparation of this discussion.

Chairman Todd: Thank you, Mr. Dasburg.

Are there any questions on this paper?

Mr. Dasburg, we want to thank you on behalf of the AREA for a most entertaining and instructive talk. What you have told us will be helpful, particularly to my committee, which has an assignment now involving roller-bearing cars.

Mr. President, this concludes the report of Committee 14 at this time.

President Miller: Thank you, Mr. Todd. As in the past, your committee has presented a number of valuable and interesting reports. As suggested by your committee, I hope that those especially interested and qualified will give careful consideration during the coming year to the proposed specifications for the manufacture and installation of four-section motor truck scales, looking to their adoption at the 1956 convention in perfect form.

We also thank Mr. Dasburg for his interesting address.

Your committee is now excused, with the thanks of the Association.

The next committee to make report is Committee 16—Economics of Railway Location and Operation, of which Mr. H. B. Christianson, Jr., division engineer, Chicago, Rock Island & Pacific Railroad, is chairman.

Will Mr. Christianson and his committee please come forward? Mr. Christianson, the floor is yours.

Discussion on Economics of Railway Location and Operation

(For report, see pp. 323–342.)

(President G. W. Miller presiding.)

Chairman H. B. Christianson, Jr. (Rock Island): Committee 16 had an active year in 1954. We report today on four of six assignments. One report is on Revision of Manual. We have two final reports as information and one which is a progress report.

The subcommittee on Revision of Manual has as its chairman Mr. A. L. Sams, office engineer of the Illinois Central. Mr. Sams, may we have your report?

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman A. L. Sams (Illinois Central).

Mr. Sams: In 1952 this committee was requested to review the Manual chapter on Complete Roadway and Track Structure, and to include that material, with appropriate revisions, in Manual Chapter 16.

The material consisted of two parts, first, a Traffic Classification of Railway Main Tracks, and second, Schedule of Classes of Complete Roadway and Track Structure.

Part 1 was approved for incorporation in Chapter 16 at the 1953 convention, and Part 2 was withdrawn pending revision to conform to the reprinted Manual. These revisions have now been completed, and your committee recommends that the report be accepted as information, and a reference to the schedule of classs be included in Part 4 of Chapter 16 of the Manual.

I should like to say this about the Traffic Classification and the Schedule of Classes. They are intended to serve as an index to the present Manual material, and not as a master set of specifications for track structure under any given operating conditions.

While speed and volume of traffic are, in general, the yardsticks by which we measure our track requirements, there are many other physical and economic conditions that must be taken into account.

Mr. Chairman, I move that the report of this subcommittee be accepted as information, and that a reference to the Schedule of Classes of Complete Roadway and Track Structure be included in Chapter 16 of the Manual.

(The motion was regularly seconded, was put to a vote, and carried.)

Chairman Christianson: Assignment 2—Economics of Retarder-Equipped Yards for Classification Switching, will be reported by Mr. H. A. Lind, senior assistant engineer, Chicago, Burlington & Quincy Railroad.

Assignment 2—Economics of Retarder-Equipped Yards for Classification Switching, collaborating with Committee 14, Signal Section, AAR, and American Association of Railroad Superintendents, was presented by Subcommittee Chairman H. A. Lind (Burlington).

Mr. Lind: The report is submitted as information, to summarize the economic advantages derived from the retarder method of car classification. It includes a list of such yards constructed in the United States and Canada, showing the railroad, yard location and number of tracks, as well as the year placed in service, with reference to published articles describing the layout.

Reference is also made to published economic reports on retarder yard installations. This method of car classification is gaining momentum, so we hope the economic data and reference material will be useful to those railroads interested in terminal improvement possibilities.

Your attention is directed to one inconsistency in the tabulation of retarder yards. The Seaboard Air Line yard at Hamlet is shown as 80 tracks; while the yard has been designed for ultimate expansion to 80 classification tracks, the initial construction included only 58 such tracks.

This is a final report, submitted as information.

President Miller: Thank you, Mr. Lind.

Is there any discussion in connection with this report?

This list of retarder classification yards will certainly be of interest to anyone who is planning a new yard, and I'm sure that—as has been the practice in the past—any road will be glad to supply you detailed information about its particular yard.

In connection with the Quebec, North Shore & Labrador Railroad, it was very interesting to note how flat the grades are in the classification yards. I had hoped there might have been time for some discussion in connection with that. I noticed that the grade was 0.12 for the loaded cars, and about 0.25 for the empties, which is certainly something new in yard grades.

Chairman Christianson: Assignment 3 is Cause and Effect of Derailments and Dragging Equipment. The chairman of that subcommittee, W. E. Quinn, is not present today. Mr. C. L. Towle, chief engineer of the Detroit, Toledo & Ironton, will present the report.

Assignment 3—Cause and Effect of Derailments and Dragging Equipment, Collaborating with Committees 3 and 5, was presented by C. L. Towle (Detroit, Toledo & Ironton) in the absence of Subcommittee Chairman W. E. Quinn (Louisville & Nashville).

Mr. Towle: This is a final report, submitted as information.

Questionnaires sent out to members of Committee 16, representing 32 railroads, resulted in only 4 replies, submitting such information as was available. A compilation of these 4 replies showed the magnitude of this subject, in that answers received covered 235 derailments with a total damage cost of $1,400,000. A breakdown of these derailments might be of interest.

Ninety were equipment failures, consisting of 33 wheel and axle derailments from broken or burned-off journals; 31 derailments were from defects in car bodies; 15 derailments from brakes and brake rigging; and 9 derailments were from draft rigging failures. Of the remaining 145 derailments, 82 were caused by employee failures, 22 by track failures, and 41 by miscellaneous causes. No separation was available for derailments caused by dragging equipment.

It is regrettable that in general practice very few permanent and accurate records are kept of the cost of derailments, except in cases where the cost is billed against an industry or other railroad.

In view of the enormous cost of derailments—which in 1952 amounted to over $28,000,000—it is recommended that the attention of operating officers be directed to this report in order that in this period of rising costs early effort may be made to obtain proper cost information on this subject, to reduce a large portion of this unproductive expenditure.

Mr. President, it is recommended that this subject be discontinued for the present.

President Miller: Thank you, Mr. Towle. Your report will be received as information.

Chairman Christianson: Assignment 4 is an interesting one—Economics of "Highway Trailers on Flat Cars" Service. Mr. F. N. Nye, director of transportation research, of the New York Central System, will present this report.

Assignment 4—Economics of "Highway Trailers on Flat Cars" Service, Collaborating with the American Association of Railroad Superintendents, was presented by Subcommittee Chairman F. N. Nye (New York Central).

Mr. Nye: Committee 16's report summarizes the background of this phase of coordinated transportation and describes its status as of last fall, following findings by the Interstate Commerce Commission that railroads could establish such services either under their own tariffs or in cooperation with motor common carriers under joint tariff arrangements.

During the last several months there has been a progressive but not spectacular expansion of trailer-on-flat-cars services. Many individual railroads have installed the necessary equipment, both trailers and flat cars. Some represents a conversion of old equipment; some is new and of an experimental nature.

Some doubt still exists as to the profitability of such operations and their competitive implications. The movement of shippers' freight in both carload and less-carload trailers under railroad tariff rates competitive with truck rates has been rather disappointing as a source of new traffic. The handling of motor carriers' trailers under joint tariffs, although now expanding, has not yet fully proved itself economically. Thus far, operations are largely based on conventional highway semi-trailers and more or less conventional flat cars. The trend toward 75-ft flat cars with high-speed trucks designed to accommodate two semi-trailers may be developing. This may lead to depressed decks as well as flat surface decks.

Some equipment experimentation is going on. A recent design involves lifting the trailer's rubber-tired wheels free of the flat car deck by transferring the load to dolly wheels affixed to their axles. These dolly wheels roll along and are fastened to what is, in effect, a raised center sill of the car. This novel design, using end loading, is said to reduce loading and unloading time and costs, and makes for less expensive terminal facilities.

In addition, ingenious designs for highway trailers and transferable trailer bodies are also being promoted. No doubt, the present year will produce further developments and economical evaluations, which Committee 16 proposes to review and bring to the attention of our membership in a further report.

President Miller: That is a very interesting report, Mr. Nye.

I wonder if there is anyone in the audience who would like to ask any questions? This is a very timely subject. We would like to break in our new microphone system and try it out.

D. F. Lyons (Illinois Central): Has any consideration been given to the loading of these trailers from the side, with a side-loading platform instead of a platform at the end of the tracks?

Mr. Nye: That is an alternate method of loading and unloading, and so is lifting them on and off flat cars by cranes. I think that was presented in the report made by the Committee on Yards and Terminals.

President Miller: Are there any further questions?

Chairman Christianson: Perhaps to improve the way we analyze subjects, we are studying—and we hope to prepare a monograph on—the subject, Operations Research. Mr. Q. K. Baker, president and general manager of the Quanah, Acme & Pacific Railway, is chairman of the subcommittee studying that subject.

Q. K. Baker (Quanah, Acme & Pacific Railway): Mr. President, this subject was assigned to Committee 16, and I know that we are all interested in it. We see so much about Operations Research, and, to be quite frank, a lot of us didn't even know what it means. A young man, a member of this committee, Roger Crane, has undertaken the preparation of this paper, which has just been completed and will be reviewed by the subcommittee and submitted to the membership of Committee 16 at its spring meeting. We hope to have this paper in shape, probably, to submit at the next annual meeting of the Association.

President Miller: Thank you, Mr. Baker.

Chairman Christianson: We have another subject assignment that has been plaguing us for several years. We think that now, perhaps, we have an answer. It is a graphical representation of the life of rail. Mr. L. E. Ward, chairman of the subcommittee, will report on this.

Assignment 1c—Life of Rail, was presented by Subcommittee Chairman L. E. Ward (Pennsylvania).

Mr. Ward: Your committee submits the following report of progress as information.

It is the assignment of Subcommittee 1c to bring up to date that information in Chapter 16–1–13 concerning rail life for use in determining operating data required for study of the economic justification of line and grade revisions.

Existing information presented in the Manual for cost of rail used in relocations gives us definite values in million gross tons, which each of several sections of rail should carry during its normal first laying.

Because of the multitude of factors involved in rail life, it is thought that values developed from actual experience and presented on a graph, with rail life in million gross tons of traffic, plotted against rail weight in pounds per yard for different traffic densities, would be more useful.

Approximately 260 different rail life cases were studied from information gathered by the Association's research staff from 12 different railways, covering the most commonly used rail sections under various traffic densities. From this information a curve was plotted for each weight of rail, showing rail life as related to traffic density.

A graph was then plotted relating rail life to rail weight for the various traffic densities. We are now attempting to graph rail life as a ratio relative to rail weight in pounds per yard for the various traffic densities. Thus, with the information we hope to have developed in the near future, knowing the various conditions under which it is wished to operate, the total gross tons of traffic which the rail being considered may be expected to carry could be read from the graph, expressed as a ratio of the life of that rail which has been in use on the existing line.

President Miller: Thank you, Mr. Ward.

Chairman Christianson: Among the other work done by Committee 16 last year, Mr. President, was a review of the Given paper, "Notes on Railroad Location and Construction Procedures From the School of Experience," and a very thorough editing of the Manual, showing methods and procedures for determining railway line capacity for use by the Army and the Central Intelligence Agency. Editing of this work was done under the direction of Mr. H. P. Weidman, who is not here today.

Mr. President, next year we have a very interesting assignment. We asked for it ourselves, and we hope that we can present it in the right way. This assignment is "Innovations in Railway Operations."

This morning Mr. Magee told us about some of the research that is going on in new procedures. When we first started talking about this, we called our committee a "Dreamer Committee," because, perhaps, this is the place where these dreams should be discussed. We feel that if we only make a list of future possibilities and discuss them pro and con, perhaps we will have gone a long way.

I suppose it is true that today's progressives become tomorrow's reactionaries. We would like to live in the future for a little while in this committee. If we understand the problem, that is, if we define it, perhaps here will be the genesis of some things to come.

Mr. President, if you want to try the floor microphones which have been provided, perhaps we can start right now with a few suggestions or questions from the floor.

President Miller: Thank you, Mr. Christianson.

Chairman Christianson: If there are no comments, the report of Committee 16 is concluded.

President Miller: Mr. Christianson, your committee has several new subjects in which we are all very interested. I am sure great benefit will be derived from a study of them, even though they may involve some dreaming. No doubt, some of the things you will consider will come true.

I want to thank you and the members of your committee for the highly informative reports which you have brought to us. Your committee is now excused with the thanks of the Association.

The next report to come before the convention will be that of Committee 25—Waterways and Harbors. The chairman of this committee is Mr. Arthur Anderson, special assistant engineer, New York Central System, Chicago. Will Mr. Anderson and members of his committee please take their places at the speakers' tables?

Discussion on Waterways and Harbors

(For report, see pp. 391–392.)

(President W. G. Miller presiding.)

Chairman Arthur Anderson (New York Central): Committee 25 will have no subcommittee reports this year. The feature of its presentation will be an address by Mr. Paul F. Royster, Assistant to Undersecretary of Commerce for Transportation, Washington, D. C., on the subject, Fair Play in Navigational Clearances for Bridges.

I will present Mr. P. A. Hollar, vice president and assistant to the president of the AAR, whom you all know, and I think no introduction is necessary. Mr. Hollar, will you kindly introduce Mr. Royster?

P. A. Hollar (AAR): Mr. President, Mr. Chairman and gentlemen: I think it is customary to have a speaker of the prominence of Mr. Royster introduced by someone who has known him for a while, and that is perhaps why I have been called on. I think it is also customary to tell you a little bit about the speaker, and I have something written down here on a piece of paper furnished by his secretary. But I think I would much prefer just to put that in my pocket and tell you a little bit about what I know personally about Mr. Royster.

He is a former railroad man, and for that reason I think he can be very warmly welcomed here. Mr. Royster spent 30 years on the Monon Railroad. He qualifies thoroughly as a Hoosier. He is very much of a "private enterprise" person which sometimes is a little astounding in a bureaucrat.

After Mr. Royster left the Monon Railroad, he engaged in the local transit business in Lafayette, Ind. Following that he was general manager of the local transit company in Kokomo, Ind.

During his residence in Lafayette he became the second president of the Purdue Dads Club; he had a son and daughter attending Purdue University.

I mention these things so that you can see how firmly his roots are in the private enterprise system. Also, I want to admit some responsibility for making him a bureaucrat. When I was called into government service temporarily during the Korean episode, we were looking for help from some people with some transportation training and experience. The name of Paul Royster was mentioned. After investigating him thoroughly, we immediately decided that he was the kind of person who could help in that situation.

Among his sponsors was the assistant director of the National Production Authority, a young man whom Mr. Royster had helped get through Purdue. With a recommendation of that nature, and his connection with Purdue, he made a big impression on me, because I happened to spend a little time down there myself.

Your speaker is highly qualified with respect to his particular subject today, and I think the subject is a very timely one, because only very recently has the Department of Commerce issued a study entitled Navigational Clearance Requirements for Highway and Railroad Bridges. I think the Association of American Railroads was of some help in compiling data for the department in connection with the exhibits on railroad bridges.

Before introducing your speaker, I want to read just one paragraph from this report, immediately under the heading of personal acknowledgements: "Special recognition for this report must be given to Mr. Paul F. Royster, Assistant to the Undersecretary of Commerce for Transportation, who directed all phases of the effort in behalf of the Department of Commerce."

It gives me great pleasure to introduce Mr. Royster.

Fair Play in Navigational Clearances for Bridges

By Paul F. Royster

Assistant to Under Secretary for Transportation, United States Department of Commerce

I am very grateful for the privilege of being here with you today. I am equally thankful for the invitation to discuss with you recent developments concerning a transportation issue we think is of nation-wide importance. It is the problem of navigational clearances in bridges. This subject could well be of special significance to each of you as operating officials of the railway industry.

For more than a century, when overland transportation interests, rail and highway, raised questions about the reasonableness of navigational clearances in bridges, they have been told that since waterway transportation was the first to be developed in America it has a "prior right" or an "inherent right" over land traffic at bridge crossings. The news that a proposed railroad bridge must be a high level structure, or must contain a movable span, because at some earlier date a boat navigated beyond the point of crossing, is old stuff to you, I am sure. However, a critical examination of the progress made in the various modes of transportation since the dawn of civilization fails utterly to substantiate this philosophy of priority. Indeed, a study of basic concepts embodied in American constitutional government reveals that the "prior right" of navigation is nothing more than a mythical concept. From the historical standpoint of transportation development, the "prior right" of navigation is just as mythical as is the legend that the Colossus of Rhodes straddled the inlet to the harbor of that island. I am not questioning the existence of the Colossus. It *did* exist and it was one of the wonders of the ancient world. Nevertheless, the mythical gods of those ancient days never would have permitted its construction across the waterway. It would have been an unreasonable obstruction to the "inherent right" of navigation.

Man's first migrations were on land. His efforts to lighten his load, and that of domesticated animals, as he moved from place to place, began with the invention of the wheel. This was in Asia, sometime between 8000 B.C. and 6000 B.C. A thousand or so years later, when early civilizations were gaining a foothold along the Nile River, in the Tigris–Euphrates Valley, and on the eastern shore of the Mediterranean, the Phoenicians accepted the challenge of the sea by experimenting with rafts and crude boats. It was then and there, and not until then, that man began to consider seriously the possibilities of water transportation as a form of movement. The Egyptians also conducted similar experiments on the placid waters of the Nile with sailboats and other types of craft.

The Phoenicians learned, as did the Egyptians, that the use of masts and sails greatly facilitated movement of their craft. Within a few more centuries, watercraft having high masts and billowy sails, navigated by these people, plied the Nile to its first cataract, as well as the length and breadth of the Mediterranean. Even the eastern reaches of the Atlantic Ocean became "waterways".

These developments, well recorded in history, clearly documented the origin of the problem of providing navigational clearances in bridges across navigable waterways throughout the world. The wheel—which is today represented by highway and railway transportation—was developed first; the watercraft came later. The problem I shall discuss today arises at the point where transportation by wheel intersects transportation by waterway.

Here in the United States the problem is blended with certain considerations that are not found elsewhere, or at least which do not exist elsewhere to the same degree that they exist here. For example, unlike European and other countries, where overland travel antedated travel by waterway, our early settlers did rely upon *waterway* transportation to reach American shores. They did use ships to communicate with their homelands across the ocean. Our colonies were established independent from each other, and each reported directly to the English crown. Hence, there was very little need for overland transportation routes to link them together at the outset.

Following creation of the Nation, the rapid territorial expansion westward was not immediately followed by adequate overland transport facilities. The result was that the population placed increased reliance upon inland waterways, in their natural condition, for movement. Later, the people called for waterway improvements. Indeed the importance of navigation on inland and intracoastal waterways as a form of transportation in the United States has continued to be and is today relatively greater than it was and is in other countries of the world.

Many technological advancements made in our economy—such as the diesel motor, radio and radar—have been applied to both land and water transportation. However, the standardization of moving and movable equipment which has distinguished our overland transportation system has not so far been adequately realized for equipment moving on our waterways. This apparent lag in adjustment of watercraft to meet the needs of a changing economy, this continued establishment over the years of navigational clearances in bridges to satisfy extremes in waterway traffic, was largely responsible for the decision of the Department of Commerce to initiate a nation-wide study of this problem, in the public interest.

We entered into this area of the public business for several reasons. First and foremost, the Department is charged by law with the responsibility for *improving the overall transportation system* of the United States.

Second, we recognize that the cost of all forms of transportation is ultimately borne by the general public in the cost of goods the public consumes, in the cost of the services the public receives, and in the taxes the public pays.

Third, with the transfer of the Bureau of Public Roads into the Department, we became increasingly aware of the money involved here. We found out that the expenditure of large sums of public money has been required in the construction, maintenance and operation of highway bridges for accommodation of navigational needs, without having equal or greater benefits—in the form of savings in waterway transportation costs—flow to the public. We learned that a similar situation also exists with respect to railway bridge costs for accommodation of navigational needs.

Fourth, we are firmly convinced that our expanding economy is dependent not on our waterways alone, nor on our railways alone, nor on our highways alone. All three forms of movement are needed as a coordinated surface transportation system.

Fifth, we know nothing exists in our constitutional constellation which vests any segment of our economy with "prior right" over any other segment of the economy. Our whole system of government is based upon *relative* rights, with the process of adjustment constantly taking place in all areas of activity. Certainly transportation is no exception.

Sixth, preliminary evidence indicated that there were certain aspects of this problem requiring examination which never before had been thoroughly studied. In the absence of data, for many years there have been *extreme* viewpoints concerning this problem. Some were expressed in waterway transportation circles, others were expressed in overland transportation groups.

Seventh, we believed, and we still believe, that whenever an issue that affects the public interest continues to remain unresolved because adequate data are lacking, the agencies of government concerned with the issue must accept the responsibility for getting the facts out in the open, and based upon the facts, those agencies must chart the course for an action program that reflects today's public interest.

In laying the groundwork for the study of the problem we in the Department of Commerce were interested in arriving at such an approach to the effort to solve the problem as would best serve the public interest. Because this age-old problem was and still is concerned at least in part with the effect of certain Federal laws dealing with navigational clearance matters upon the administration of other Federal laws which authorize the federal-aid highway program, we felt that we had a public duty to seek the cooperation of all federal agencies having specialized interest in the overall subject.

We recognized that we were dealing with a problem on which there had been long standing disagreement between some of the federal agencies directly concerned. Our observations at that time were that the continued controversy and indecision were attributed largely to an incomplete exploration of the facts, to claims of bias, to apparent adherence to seemingly outmoded institutional concepts, and to other related factors. We believed that under the broad approach we had developed toward seeking a true impression of the public interest, the causes of disagreement, and much of the disagreement itself, would become submerged under a preponderance of cooperatively-prepared verifiable evidence. This evidence, we contended, should be published when available.

We anticipated that a joint evaluation of all that evidence would produce mutually acceptable recommendations on a specific course of action for treatment of this problem, or possible alternative courses of action, without having any participating agency feel that it might be failing to fulfill its coordinate governmental responsibility or that it might in any way be compromising the public interest.

Summarizing our convictions and expectations, we were determined to face the issue squarely and to play fair in all phases of the study.

After obtaining Bureau of the Budget approval for the study, we in the Department of Commerce rolled up our sleeves and went to work. We played fair by inviting every federal agency having an interest in the problem, or which might in any way be affected by the outcome of the study, to participate in the nation-wide undertaking.

Within the Department of Commerce this meant the United States Coast and Geodetic Survey, which operates vessels in the conduct of its work; the Maritime Administration, which has an active and reserve merchant marine fleet and has certain responsibilities incidental to merchant vessels designed and constructed with federal financing; and the Bureau of Public Roads, the principal road building agency of the federal government, which also serves as the focal point between the executive branch of the federal government and the states on highway matters.

Outside the Department of Commerce, the invited agencies included:

The *United States Coast Guard,* which has responsibility for maintaining navigational aids in the waterways and which becomes a part of the Department of the Navy in time of national emergency. The Coast Guard has control over federally-owned watercraft needed for the performance of its work.

The *Tennessee Valley Authority,* which, together with the Corps of Engineers, is responsible for decisions concerning navigational clearances in bridges across the Tennessee River and its tributaries. TVA also owns and operates a number of watercraft.

The *Department of the Navy,* which has navigational clearances needs for accommodation of the federally-owned defense watercraft under its jurisdiction.

The *Corps of Engineers, Department of the Army,* which is responsible for navigational improvements. The Corps also determines navigational clearance requirements in bridges under laws that have been in force since the turn of the century. It has jurisdiction and immediate control over many federally-owned watercaft engaged in waterway construction and maintenance activities, and for many years it has served as the focal point between the executive branch of the federal government and the operators of privately-owned watercraft.

The *Interstate Commerce Commission,* which through its Bureau of Accounts, Cost Finding and Valuation, serves as the focal point between the federal government and the railroads on railroad valuation and related matters.

The Bureau of the Budget, Executive Office of the President, which serves as the clearing house for the president on legislative proposals and has related responsibilities for budget matters, program coordination and management improvement.

We played fair in pointing out to those federal agencies that the framework of the study called for participation by each one to the extent of its known interest. The Bureau of the Budget excluded itself from direct participation in the study, but assigned an observer to it.

No problems existed with respect to the requirements of the Maritime Administration; the United States Coast and Geodetic Survey; the Department of the Navy; and the Transportation Corps, Department of the Army. The major interest of those agencies was concerned with the navigational clearance needs of watercraft under their immediate control and with the feasibility of adjusting projections of such craft so the craft could be accommodated by reduced bridge clearances. The responsibility of the Coast Guard, which includes its own watercraft as well as navigation regulations affecting numerous other craft, presented no serious problem. The Tennessee Valley Authority was given a full opportunity to have its views recognized.

Major difficulties arose in only two areas of the effort. The first was concerned with the need for a realistic evaluation of *bridge costs* due to navigational needs. Because the Corps of Engineers, Department of the Army, for many years has been administering federal laws which control navigational clearances in bridges, we believed that that agency should be a direct participant in the proposed evaluation. We hoped that bridge cost data of *unquestioned acceptability* could be prepared through the joint efforts of the Corps of Engineers, the Bureau of Public Roads, and the State Highway Departments for highway bridges, and of the Corps of Engineers and each bridge owner for railroad bridges.

To facilitate the detailed work, the Bureau of Public Roads had devoted more than a year, including extended field study, in the preparation of uniform instructions for evaluating highway bridge costs due to navigation needs. The reasonableness of the instructions thus developed is evidenced by the fact that, following consultation with the Interstate Commerce Commission and review by its own staff, the Association of American Railroads adopted very similar instructions for evaluating the railroad bridge costs due to navigational needs.

Tentative agreement was reached at an early date for complete cooperation. However, when this phase of the effort was started, the representatives of the Corps of Engineers pointed out that their agency did not have sufficient authority or funds for this complete cooperation. Therefore, while the Corps of Engineers did participate in the preliminary planning of the study, that agency did not take part in the preparation of the bridge cost data.

The second area of difficulty was concerned with the feasibility and cost of altering watercraft projections. In the Department of Commerce, it was assumed that the Corps of Engineers could develop the information not merely for its own watercraft but also for privately owned watercraft. Several facts were well established before the Corps was invited to participate. To illustrate, we knew that the Corps had direct jurisdiction over a number of federally-owned watercraft it uses in waterway constuction and maintenance activities. We also knew that the Corps annually publishes several transportation series which list the watercraft of American registry engaged in commercial operations on specific waterway systems.

Furthermore, our observations indicated that whenever it prepares its recommendations to the Secretary of the Army as to the navigational clearances to be required for any specific bridge, the Corps of Engineers also had available data on the watercraft presently navigating the particular waterway and those which are expected to do so in the future. Here, again, the representatives of that agency pointed out after the study was started that their agency lacked the authority and the funds to develop the information relating to privately-owned watercraft. Actually, it was not until August 1954, and some time after the data-collecting process was completed by the other cooperators, that the Corps actually furnished data concerning the feasibility of modifying its own watercraft.

In mentioning the foregoing points I do not intend to suggest or imply any criticism of the Corps of Engineers. Its representatives were and are in a position to determine what authority their agency has, and what it can and cannot do. I am bringing these points to light to show that even though we in the Department of Commerce clearly recognized from the inception of the study that we were delving into an issue that has been highly controversial for more than a century, at no time have we denied any federal agency having an interest in this problem a real opportunity to take part in the study. By the same token, we made it clear in various discussions and deliberations that the Department of Commerce would not compromise its integrity and objectivity in preparing or analyzing the facts needed for a proper evaluation of this complex problem. Stated simply, we wanted to play fair with all interests and we expected fair play from them.

To overcome the deficiency of information on privately owned watercraft, we in the Department of Commerce requested the Bureau of Public Roads to prepare a detailed analysis of the watercraft listed in Corps of Engineers Transportation Series No. 4. That publication contains information concerning privately owned watercraft (except fishing craft and pleasure craft) that operate on the Gulf Intra-coastal Waterway and the Mississippi River System. The resultant gap in our compilations was caused by our reluctance to having the Department of Commerce deal directly with watercraft interests that normally reported through the Corps of Engineers. We also asked the Transportation Council of the Department of Commerce for advisory comments on the effect of navigational clearances in bridges upon transportation costs.

As stated before, the data on bridge costs due to navigational needs was prepared without participation by the Corps of Engineers. The report on our study, which was just released, climaxes the initial phases of our determined effort to highlight the need for realistic federal policies concerning navigational clearances for highway and railroad bridges.

The facts emanating from this study revealed many things. We do not wish to burden you with many details which you can obtain at your leisure by reading the report, but there are a few major items I want to mention to stimulate your interest. For example, based upon the bridges actually studied in detail we learned that the provision for accommodation of navigation, as adjusted to 1950 prices, exceeded $754 million. This amount, of course, is startling. Yet, we know that the *total* adjusted cost of construction of bridges for accommodation of navigational needs is even greater than that amount. We were unable to prepare cost data on all the bridges in this category, and tunnels were excluded from the study.

The *annual* cost of maintaining and operating bridges for accommodations of navigation is estimated at $16.0 million, and the annual cost of vehicular and train delays resulting from navigational requirements is *no less than $11 million.*

At least 21 movable-span highway bridges in 13 states, and at least 2 movable-span railroad bridges, never have been opened for the accommodation of watercraft. No less than 375 movable-span highway bridges in 30 states and 179 movable-span railroad bridges are opened on an average of once a day or less. Some 425 movable-highway and railroad bridges were reported as not having been opened for a year or longer.

The relative infrequency of many movable-span bridge openings was further explained by detailed analysis of Corps of Engineers Transportation Series No. 4, which, as I have mentioned, lists watercraft of American registry (except fishing craft and pleasure craft) operating on the Gulf Intracoastal Waterway and the Mississippi River System. Of a total number of 9953 watercraft listed, only 1780 (or 18 percent) have projections which extend above 25 ft when the craft are light; only 1103 (or 11 percent) have projections above 30 ft, only 556 (or 5.6 percent) have projections above 40 ft, and only 79 craft (less than 1 percent) require the established clearances. It is small wonder that overland transportation interests for many years have questioned the need for a minimum vertical clearance of 72 ft on the Gulf Intracoastal Waterway.

The study also revealed a very significant thing which could be of particular interest to you. It disclosed that while it is true that the railroad interests have been presenting statements at Corps of Engineers hearings on proposed navigation projects, or concerning the establishment of navigational clearances in bridges, the statements generally failed clearly to point out the relationship between added railroad bridge costs due solely to navigational needs and the economic justification of navigation projects. This failure to be specific likewise is true in many of the statements that have been filed by highway interests. However, we would like to call to your attention a paragraph which we found in a statement filed by the Mississippi State Highway Department at a Corps of Engineers hearing in December 1952, concerning proposed waterway improvements on Chunky Creek, the Chickasawhay River, and the Pascagoula River. The paragraph reads:

> "Since the existing federal laws provide in effect that bridge clearances should be determined by the Corps of Engineers, this Department would greatly appreciate a formal expression from your office as to the horizontal and vertical clearances expected to be required on these waterways, together with details of the proposed channel alterations, and highway relocations that might be involved. With this requested information on hand, it should be possible for us to furnish you with an estimate of the effect that the contemplated improvements, if undertaken, would have upon highway transportation development. These figures, when considered with the comparable figures which, it is presumed, you will obtain with respect to railroads, should provide your office with the additional facts needed, in our opinion, to make any recommendation to Congress."

Because the entire statement clearly describes overland and waterway transportation relationships at bridges across navigable streams, we included it as an Appendix in the Department of Commerce report. That statement touches upon the essence of this whole problem. It preaches fair play. On the one hand, it clearly respects the right of the Corps of Engineers, under existing laws, to determine what waterway improvements that agency may recommend for navigational purposes, and what kind of navigational clearances it may require for accommodation of watercraft. On the other hand, it asks the Corps of Engineers to respect the *equal* right of the overland transportation interests to determine how much the navigational clearances that agency requires in bridges will increase overland transportation costs, and to have those figures included in navigation project reports that are submitted to the Congress.

Recent developments indicate that the Corps of Engineers already has begun to recognize the equity of these views. In October of last year, representatives of the Department of Commerce and of the Corps of Engineers completed lengthy discussions in arriving at a statement of Corps of Engineers views for inclusion in the Commerce report.

Immediately following those discussions, in fact even before we had obtained the formal views of the cooperating federal agencies concerning our report, the Corps of Engineers spelled out to its people a policy that an economic analysis of comparative costs and benefits should be made in bridge clearance cases. According to General E. C. Itschner, the very able assistant chief of engineers in charge of Civil Works, who presented a paper before the Mississippi Valley Association on February 7, 1955, the analysis is used as one part of the study leading to the final decision as to what constitutes an unreasonable obstruction to navigation.

Because for at least two years we faced many criticisms and absorbed untold frustrations in our effort to keep this navigational clearance study alive and moving forward, we derive a feeling of personal satisfaction in quoting further from General Itschner's paper. He stated:

> "Some of the data for the analysis originates with the navigational interests, who must analyze the characteristics of waterway commerce passing the intersection in question and determine the resultant damages or losses if certain restrictive clearances are provided.
>
> "Conversely, navigational interests must demonstrate the resulting benefits in terms of dollars to be realized by the provision of clearances proposed by them. The problem resolves itself into one where both land and water transportation interests must fully consider the economic effects of the final decision on the overall economy of the region."

That statement, and the policy directive issued earlier by the Corps of Engineers, are current evidence that the Corps of Engineers earnestly desires to play fair in arriving at decisions on this subject. Some of you who have been confronted with the problem of what appeared to be unreasonable and uneconomic navigational clearances in bridges for many years, and some of the highway interests who have had similar experiences, may well be saying: "at long last!" However, we in the Department of Commerce, who are charged with responsibility for continued treatment of this problem feel that at present we stand merely at the beginning in a new era of understanding of "fair play" policy on this subject.

Not too long ago it was suggested to me that the concept of fair play, which from the start the Department of Commerce has been carefully shaping into this activity, should not be limited to the federal agencies involved. The proposal that was made called for active participation by *all* public and private surface transportation interests—waterway, rail, highway, and pipeline. In effect, it provided that before final decisions are reached by the responsible federal official on such matters as the classification of navigable waterways, or the establishment of standard navigational clearances for bridges, all the affected surface transportation interests, as an advisory committee, would be given a real opportunity to explore the overall problem on a regional basis. The regional advisory committee would point out the areas of agreement and any indicated areas of disagreement on the problems assigned to it. The range of any disagreements would be noted. The committee report would be furnished to the responsible federal administrator who would exercise his discretion in applying its recommendations to his decisions.

The proposal was made on the theory that such an advisory committee with adequate representation, in highlighting the areas and the degree of disagreement, would be able to pinpoint specific problems requiring careful analysis by the responsible federal administrator. The suggestion to me was accompanied by a request that it receive earnest consideration. The views of all the affected transportation interests on such a proposal would be most interesting.

I should like to end this discussion on a note of high hope that as a result of the work done on this particular phase of your many problems, substantial progress may be made in your continuing struggle for greater efficiency and economy in your railroad operations.

Chairman Anderson: Thank you, Mr. Royster, for your interesting and informative talk on a matter which is of great importance to the railroads. Also, thank you, Mr. Hollar.

I would like to add here that the report referred to by Mr. Royster is entitled Navigational Clearance Requirements for Highway and Railroad Bridges, and copies are available by writing to the United States Department of Commerce, Room 6225, Commerce Building, Washington 25, D. C. And do not fail to enclose $1.50 per copy.

We have a little committee business to attend to now.

I would like to mention first that two of our members died during the past year—Mr. G. A. Knapp, special engineer, Joint Railroad Special Committee, Houston, Tex., and Mr. J. L. Vogel, retired engineer of structures, Delaware & Lackawanna Western Railroad, Hoboken, N. J. Suitable memoirs have been prepared that will be included in the Proceedings.

MEMOIR

George Albert Knapp

October 13, 1954, marked the passing of George Albert Knapp, who for many years served the southwestern railroads as an expert on competitive transportation matters.

Mr. Knapp was born in Baltimore, Md., on October 16, 1881, and received his technical education at Lafayette College and Baltimore Polytechnic Institute. Early in his career his experience was wide and varied, having been gained in various capacities on Central American as well as North American railroads.

At the outbreak of the first World War he entered the army training school at Fort Leavenworth and passed through the ranks of student officer, captain and major. Corps of Engineers. On April 8, 1918, he was promoted to the rank of lieutenant colonel and immediately joined the American Expeditionary Forces in France, where he served until late in September 1919.

At the time of his death Mr. Knapp had held membership in the American Railway Engineering Association for about nine years and during this time had served on Committee 9—Highways, and Committee 25—Waterways and Harbors. He was also a member of the Association of American Railroads' Committee on Waterway Projects, and chairman of the committee's Zone 11.

The greater part of Mr. Knapp's career was spent in the service of the Southern Pacific Lines, which he served as special engineer on valuation matters until September 1947, when he was granted leave of absence to engage in study and research of competitive transportation, on which subject he was an outstanding authority, having many times dealt effectively with governmental agencies in presenting the railroads' case when projects detrimental to their interests were proposed. On this assignment he served until October 16, 1951, when he reached the age of 70 and was retired from active railway service under the regulations of his company.

Upon retirement he continued his activities in the field of competitive transportation as special engineer in charge of waterway work of the Joint Railroad Special Committee in behalf of all the railroads in Texas.

Mr. Knapp was a member of the Lutheran Church, a Mason and a Shriner. He also held memberships in Sigma Chi fraternity, the Engineers' Club of Houston, and the Leon Springs First Officers' Training Camp Association.

With his passing the railroads have lost a champion in their fight against the inroads of subsidized competition. The vigor and force of his efforts in their behalf will be long remembered.

MEMOIR

John Leonard Vogel

John L. Vogel, retired engineer of structures of the Delaware, Lackawanna and Western Railroad, died at his home in Manasquan, N. J., on August 23, 1954, following a short illness.

Mr. Vogel was born February 29, 1884, in Jersey City, N. J., where he attended public schools. He received his engineering education at Cooper Union, New York. He started his engineering career with the American Bridge Company in 1901 and subsequently served with W. H. Post, consulting engineer; the Central Railroad Company of New Jersey as designer and assistant bridge engineer; the Public Utility Commission of New Jersey as principal assistant engineer; the New Jersey State Highway Department as bridge engineer; and from 1925 until his retirement in 1954 he was engineer of structures of the Delaware, Lackawanna and Western.

Mr. Vogel was a Life Member of the American Society of Civil Engineers and the American Railway Engineering Association, and had served on Committees 7, Wood Bridges and Trestles, and 25—Waterways and Harbors, of the latter organization.

He was very active in community politics for the past 30 years, serving as councilman, tax assessor, and president of the Borough Council, and for 8 years, mayor of Manasquan. He was also senior warden of the Church of St. Uriel the Archangel in Sea Girt, N. J., at the time of his death.

Mr. Vogel was a man of great energy and force, with an extraordinary capacity for work. He gave unstintingly of his time to his work, home, church and community. He is greatly missed by all his friends and business associates.

Chairman Anderson: Under the rules of the Association, the chairman and vice chairman serve for a period of three years. That period has now expired for the present chairman and vice chairman, and a new chairman and vice chairman will now take over.

I wish to thank Mr. Howard and his staff, and members of the Association who have assisted the committee during the past three years. It is much appreciated.

Now, I wish to introduce the new vice chairman, of our committee—Mr. F. B. Manning, engineer of bridges and structures, Northern District, Chesapeake & Ohio Railway, Detroit, Mich. (Applause)

Next, I would like to introduce the new chairman, A. L. Sams, office engineer, Illinois Central Railroad, Chicago. (Applause)

That concludes our presentation.

President Miller: Before I proceed to make a presentation to the new chairman of Committee 25, I would personally like to thank our speaker today. I know he has a train to catch, and so that he may be released, I would just like to say to him, on behalf of our Association, that the work which he and his department are doing is certainly something that we have been in need of for many years. Greater understanding and fair play are things we can adopt in all of our work. They should be the basis of every engineer's study.

Thank you very much, Mr. Royster. (Applause)

Mr. Anderson, the Association is deeply appreciative of your leadership of Committee 25 since 1952, when your committee was reactivated. There is a real need for your committee within the committee framework of our Association.

And we are very fortunate in your successor as chairman—Mr. Sams, who we are sure will carry forward the work of the committee aggressively for the next three years.

If Mr. Sams will please stand, I would like to present him with a chairman's gavel, as a symbol of his authority in the conduct of his committee meetings. The band on the gavel reads, "A. L. Sams, Chairman, Committee 25, 1955–1957." (Applause)

Mr. Sams, we are sure that you will use this gavel with distinction throughout your term as chairman.

Mr. Anderson, speaking for the Association, I would like to thank you for bringing Mr. Royster to us today. Your committee is now discharged with the thanks of the Association.

(Vice President G. M. O'Rourke assumed the chair.)

VICE PRESIDENT O'ROURKE: The next committee to report to the Association is Committee 9—Highways, of which Mr. W. C. Pinschmidt, engineering assistant to vice president—construction and maintenance, Chesapeake & Ohio Railway, is chairman. May I ask Chairman Pinschmidt, the vice chairman, the secretary of the committee, and all of the subcommittee chairmen to take their places at the main speakers' table on the upper platform, and the other members to find their places at the committee table directly in front of me, filling out any vacant chairs at the main speakers' table?

I would like to repeat the president's invitation to the membership for questions or discussion from the floor.

Mr. Pinschmidt, you may proceed with the presentation of your committee report.

Discussion on Highways

(For report, see pp. 369–382.)

(Vice President O'Rourke presiding.)

CHAIRMAN W. C. PINSCHMIDT (Chesapeake & Ohio): The report of Committee 9 is found in Bulletin 518, beginning on page 369. There are four assignments on which the committee will report. On three other assignments the committee has made progress during the year, but is not presenting reports at this time. The chairmen of the subcommittees working on these three assignments are Messrs. J. E. K. Krylow, T. M. Vanderstempel, and J. A. Jorlett.

The first report to be submitted is on Assignment 1—Revision of Manual. Mr. C. I. Hartsell, division engineer, Chesapeake & Ohio Railway, is chairman of the subcommittee, and will present the report.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman C. I. Hartsell (Chesapeake & Ohio).

MR. HARTZELL: In its continuing effort to clarify, simplify and standardize the highway portion of our Manual your committee recommends the deletion of present Figs. 1, 2, 3 and 4 showing Highway Crossing Signs, substituting therefore Figs. 1, 2, 3 and 4 showing Highway Crossing Signs with revised notes and titles as contained in Bulletin 518. Mr. President, I so move.

(The motion was regularly seconded, was put to a vote, and carried.)

Your committee believes that the present chart of Recommended Use of Highway–Railway Grade Crossing Signals in the Manual should be expanded to include the recommended use for the "No Right Turn" and "No Left Turn" signals. Mr. President, I move the deletion of the present chart and substitution of the revised chart of Recommended Use of Highway–Railway Crossing Signals as contained in Bulletin 518.

The Manual now contains requisites for "No Right Turn" or "No Left Turn" signals. So that we may more readily refer to them and place them with other signal plans and requisites, your committee recommends the reapproval of the requisites and the re-numbering of the pages, placing the requisites in Part 2 of Chapter 9 in the Manual. Mr. President, I so move.

(The motion was regularly seconded, was put to a vote, and carried.)

The plan for "No Right Turn" or "No Left Turn" signal has been revised as to notes contained on the figures and the notes have been clarified. Mr. President, I move that Fig. 11, "No Right Turn" or "No Left Turn" signal, as published in Bulletin 518, be substituted for the present Fig. 1 in the Manual on page 9–M–14.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. President, this concludes the report on Assignment 1.

Vice President O'Rourke: Thank you, sir.

Proceed, Mr. Pinschmidt.

Chairman Pinschmidt: The chairman of the next subcommittee, Mr. R. E. Nottingham, division engineer, Louisville & Nashville Railroad, is unable to be here today. Mr. Nottingham has contributed much time and effort toward the preparation of the specifications for highway grade crossings over railway tracks contained in the Manual. The current assignment covers design and specifications of open grating type crossings. However, upon recommendation of Committee 9, the Board Committee on Outline of Work has changed the assignment to read, Merits and Economics of Metal Grating Type Crossings. The committee is continuing its study on this basis.

I am sure Mr. Nottingham will appreciate receiving from the membership any data pertaining to this type of crossing. The report is presented as information. If there are any suggestions at this time, the committee would certainly be glad to hear from the membership.

Vice President O'Rourke: If anyone on the floor has a question or suggestion, comments or discussion, please stand and raise your hand, and the bellman will give you a microphone. Please state your name and your railroad.

Robert C. Hill (Erie Mining Company): We have a question regarding the use of this grating-type crossing, and that is its applicability in regions where we have game crossing the road. Are we going to encounter any difficulty with game, such as deer, becoming entangled in the crossing? Has this matter been discussed or considered at all?

Chairman Pinschmidt: I must confess that is a new angle, and something to which the committee would be glad to give consideration. Have you any suggestions in that regard?

Mr. Hill: In that regard, I note that a number of manufacturers do furnish the smaller size or type of grating which will permit animals to cross over without punching through the grating. Perhaps this would be the answer to my question. I would appreciate any recommendations you might have to make.

Chairman Pinschmidt: Thank you for the suggestion.

Now, are there any further remarks? I am sure our subcommittee chairman is hopeful for further discussion on this subject. If you have anything in mind that will be helpful, we would like to hear it.

Vice President O'Rourke: If there is nothing further, proceed, Mr. Pinschmidt.

Chairman Pinschmidt: Assignment 4 covers an outline to guide highway departments and others in making applications for easements, etc. Mr. E. R. Englert, assistant engineer, Louisville & Nashville Railroad, chairman of the subcommittee, has also been detained. In his absence I shall present the report of the committee.

Assignment 4—Outline to Guide Highway Departments and Others in Making Applications for Easements, etc., was presented by Committee Chairman

W. C. Pinschmidt in the absence of Subcommittee Chairman E. R. Englert (Louisville & Nashville).

Chairman Pinscmidt: Most of us know that railways receive requests from highway departments and others for highway, street and private roadway easements. Almost invariably there will be too little of certain information and often too much of other unnecessary information. Frequently, railway company engineers have to make extensive field surveys before it is possible to determine what effects the requested easement may have on railway property and operations.

The outline or guide that has been developed by the committee calls for the submission of a plan, a profile, details of drainage, cross sections, and a plat suitable for attachment to the easement document. It also includes information about the formalities of submitting the application.

This outline may not fully serve the needs of every railroad, as there are, no doubt, some items that have not been included. However, the committee feels that publication of the outline will give highway engineers and others concerned a good idea of what is required, and that it should be included in the manual.

The report is presented as information, with the view to recommending its adoption for printing in the Manual next year. The committee welcomes your comments and criticisms.

Vice President O'Rourke: Are there any comments?

Your report will be so received, Mr. Pinschmidt.

Chairman Pinschmidt: The assignment on which Subcommittee 7 has been working for several years is one that has caused much thought, study and discussion. However, the committee feels that the report in its present form is ready for consideration by the Association.

Mr. J. M. Trissal, assistant chief engineer, Illinois Central Railroad, is chairman of the subcommittee, and will present the report.

Assignment 7—Sight Distance at Highway–Railway Grade Crossings, was presented by Subcommittee Chairman J. M. Trissal (Illinois Central).

Mr. Trissal: Mr. Vice President, gentlemen:

Your committee studying sight distance at highway–railway grade crossings has given a great deal of consideration to the multiplicity of problems involved in order to make recommendations on this subject. Our report is based on a theoretical study of the time, velocity and distance factors of highway and railroad traffic intersecting at grade crossings where manual or automatic protection is not supplied. The sight distances involved, for all practical purposes, limit their application to rural areas. It will be noted that there are no factors of safety allowed to take into account slippery pavements, poor brakes, slow driver reactions, down grades or other variable items. These factors of safety are omitted primarily because we do not know how to incorporate them in a manner which would cover all conditions.

It will also be noted that the maximum speed of automotive vehicle considered is 40 mph, as it is the feeling of your committee that if higher speeds were considered, the size of the area required to afford sight distance would be beyond reason.

Your committee has also given considerable thought to the possible trap which is set up by providing sight distance in the manner shown. By possible trap, we mean that if a driver does not become aware of a train until he is closer to the railroad track than the sight distance afforded and tries to stop, a collision is very likely to result. To be safe, the driver must continue at the designated speed and thus will pass in front of the train. This is contrary to the normal reaction of the driver, and has caused considerable discussion among the members of your committee.

Consideration is being given to studying the subject with the viewpoint of recommending safe automotive speeds based on the sight distance available. In this manner safety at crossings would be dependent on effective speed control and the alertness of drivers.

It is recommended that the subject be continued.

Vice President O'Rourke: Are there any comments, questions or suggestions from the floor?

The report will be so received, Mr. Trissal.

Chairman Pinschmidt: Mr. Vice President, this concludes the report of Committee 9.

Vice President O'Rourke: Mr. Pinschmidt, yours is one of the valuable committees of our Association, and we appreciate the diligence of its efforts during the past year under your direction. We particularly appreciate your watchfulness of your chapter in our Manual of Recommended Practice, and the recommendations which your committee has presented this year in order to improve the recommendations of the Association with respect to highway crossing signs and highway–railroad grade crossing signals.

Your committee is excused with the thanks of the Association.

The next committee to report is Committee 20—Contract Forms, of which Mr. G. W. Patterson, assistant chief engineer, Central Region, Pennsylvania Railroad, is chairman. Unfortunately, Mr. Patterson is recuperating from a period of ill health and is unable to be at our convention this year. Accordingly, the report of the committee will be presented by the vice chairman of the committee, Mr. W. D. Kirkpatrick, assistant to the chief engineer, Missouri Pacific Lines.

Incidentally, since Mr. Patterson is completing his third year as chairman of Committee 20, Mr. Kirkpatrick will become the chairman of this committee at the close of our convention.

Will Mr. Kirkpatrick and members of his committee please come to the platform?

Discussion on Contract Forms

(For report, see pp. 383–390.)

(Vice President O'Rourke presiding.)

Vice Chairman W. D. Kirkpatrick (Missouri Pacific): Mr. President, members of the Association and guests: I am sorry that our very able chairman, Mr. G. W. Patterson, is unable to attend our convention this year due to a rather severe illness from which, I am happy to say, he is recovering satisfactorily. Mr. Patterson has requested me, as vice chairman, to present the report of Committee 20 in his absence.

During the past year your committee has seen fit to award the honorary degree of Member Emeritus to two more of its retired members, namely, Mr. O. K. Morgan, formerly consulting engineer, Piedmont & Northern Railway, and Mr. F. L. Nicholson, formerly chief engineer of the Norfolk Southern Railway. Both men had given long and valuable service to this and other committees, and were well qualified to receive the award.

Shortly after the award to Mr. Nicholson, however, we were saddened by news of his death on May 24, 1954. A memoir in his honor was published in Bulletin 517.

During the past year Committee 20 has undertaken the study of six assignments, five of which were carried over from the previous year and two of which have now been brought to conclusion. The complete report may be found in Bulletin 518 for the month of November, 1954, page 325, and will appear in Vol. 56 of the Proceedings, same page.

The report on Assignment 1—Revision of the Manual, will be presented by Mr. W. R. Swatosh, assistant superintendent of construction of the Erie Railroad, chairman of the subcommittee.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman W. R. Swatosh (Erie).

Mr. Swatosh: The revisions proposed in the Form of Construction Contract, in the main, consist of changes and additions in order that the text of this form will be in harmony and on a current basis with other Manual agreements.

It is pointed out that the insurance provisions, as revised, specifically provide insuring of contractual liability assumed under the indemnity provisions of this agreement.

The agreement appearing in the Manual provides for furnishing a specific performance bond, but contains no provision for its cancellation. It was considered desirable to include a cancellation provision.

The committee, therefore, recommends the reapproval of the Form of Construction Contract, together with the approval of the changes and additions as set forth in the report. I so move.

(The motion was regularly seconded.)

Vice President O'Rourk: It has been moved and seconded that the revision of the Manual, as suggested by Mr. Swatosh, be carried out. Are there any comments or questions?

A. T. Powell (Grand Trunk Western): I have a question. On page 384 of this Bulletin, your committee states that the policies shall be endorsed to cover contractual liability of the contractor. Why is it necessary to have a policy cover such liability? Isn't the financial status of the contractor investigated prior to sending out the contract for bids?

Mr. Swatosh: That is a very good question, and a lengthy one.

Yes, contractors are investigated before invitations for bids are sent out. However, the indemnity provisions of the contract impose a liability upon the contractor that he generally insures against insofar as his legal liability is concerned, but when he signs a contract, he assumes liability over and above his legal requirements, and it is therefore considered desirable to have this liability that he assumes—over and above his legal liability—insured. It is felt that the railroad gets protection in that way.

Vice President O'Rourke: Is there any further discussion of the subject? Are you ready for the question?

(The motion was put to a vote, and carried.)

Mr. Swatosh: As to the Form of Agreement for the Use of Railway Property by High-Pressure Pipe Lines, with Special Reference to Pipe Lines Carrying Inflammable Oil and Gas: During the last couple of years, Committee 1—Roadway and Ballast, has gone to some length to eliminate the word, "inflammable," from its specifications for pipe line crossings under railroad tracks, and has substituted therefor the word, "flammable." Accordingly, the committee feels that it is desirable to use the word, "flammable," in the heading of this agrement, in order that it and the specifications are in harmony in this respect.

In collaboration with Committee 4 of the Signal Section, this agreement is being expanded to provide for the installation of cathodic protection of pipe line crossings at time of initial construction.

The committee recommends reapproval of the Form of Agreement for the Use of Railway Property by High-Pressure Pipe Lines, with Special Reference to Pipe Lines Carrying Inflammable Oils and Gas, together with the approval of adding cathodic protection to Sec. 3, and the use of the word, "flammable," in the heading of the form. Mr. Vice President, I so move.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. Swatosh: That completes the report of Subcommittee 1.

Vice President O'Rourke: Thank you, sir.

Vice Chairman Kirkpatrick: Assignments 2 and 3, which apply respectively to the development of a Form of Agreement Covering Subsurface Rights to Mine Under Railway Property, and Form of Agreement covering the same with respect to non-carrier property, are being studied by the same subcommittee.

Mr. I. V. Wiley, assistant engineer of the Chicago, Milwaukee, St. Paul & Pacific Railroad, subcommittee chairman, will present the report.

Assignment 2—Form of Agreement Covering Subsurface Rights to Mine Under Railway Carrier Property,

and

Assignment 3—Form of Agreement Covering Subsurface Rights to Mine under Railway Non-Carrier Property, were presented by Subcommittee Chairman I. V. Wiley (Milwaukee Road).

Mr. Wiley: Last year your committee presented, as information, a tentative draft of Form of Agreement Covering Subsurface Rights to Mine Under Railway Carrier Property, and asked for comments and criticism from the members. A number of minor revisions have been made, and the committee now recommends the adoption and publication in the Manual of the revised form.

Mr. Chairman, I move that this convention accept the form for publication in Part 7, Miscellaneous Agreements of Chapter 20 of the Manual.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. Wiley: The study of Assignment 3, which, incidentally, has been changed by the Board of Direction to read "Form of Lease Covering Subsurface Rights to Mine Under Railway Miscellaneous Physical Property," is progressing, but is not ready for a report to this convention.

Vice President O'Rourke: Thank you, sir.

Proceed, Mr. Kirkpatrick.

Vice Chairman Kirkpatrick: Assignment 4 covers the preparation of a Form of Lease for Development of Oil and Gas on Railway Lands. Mr. K. A. Begemann, assistant engineer, Missouri Pacific Lines, and a member of the subcommittee, will present the report.

Assignment 4—Form of Lease for Development of Oil and Gas on Railway Lands, was presented by K. A. Begemann (Missouri Pacific).

Mr. Begemann: In 1952 your committee submitted as information a tentative form for the subject matter of this form of lease, and requested comments and criticisms from members of the Association. The assignment was temporarily dropped during the year following, due to the urgency of completely reviewing the chapter incident to reprinting of the new Manual.

The study was revived in 1954, and with some changes, the form was again submitted as information. Subsequently, minor revisions were made, and your committee now recommends the form for adoption and publication in the Manual.

Mr. Vice President, I so move.

(The motion was regularly seconded, was put to a vote, and carried.)

Vice Chairman Kirkpatrick: There is no report on Assignment 5 this year.

Assignment 6 covers the preparation of a Form of Agreement for Turnpike or Toll Road Crossing Railway Tracks and Property. In the absence of Mr. J. W. Wallenius, chairman of the subcommittee, Mr. E. M. Hastings, Jr., wire crossing engineer of the Chesapeake & Ohio Railroad, will present the report.

Assignment 6—Form of Agreement for Turnpike or Toll Road Crossing Railway Tracks and Property, was presented by E. M. Hastings, Jr. (Chesapeake & Ohio) in the absence of the J. W. Wallenius (Pennsylvania).

Mr. Hastings: Considerable work has been done during the past year, but the form is not yet in proper shape for submission. The study will be continued, and a tentative form will be submitted as information at the next meeting of the Association.

Vice President O'Rourke: Thank you, sir.

Proceed, Mr. Kirkpatrick.

Vice Chairman Kirkpatrick: I would like to conclude our presentation by thanking—on Mr. Patterson's behalf as well as my own—the Association's secretary, the subcommittee chairmen, and all members of Committee 20 for their efforts and cooperation during the past year.

Mr. Vice President, this concludes the report of Committee 20.

(President Miller resumed the chair.)

President Miller: Mr. Kirkpatrick, we are very sorry that Mr. Patterson couldn't be here today to direct the presentation of your committee's report, especially since that would then be the crowning feature of his three years' work as chairman. We congratulate him upon the effective leadership which he has given to your committee, and wish for him an early and full recovery.

I congratulate you upon your handling of the committee's presentation in Mr. Patterson's absence, and upon your appointment as chairman of Committee 20. To assist you in the conduct of your committee work for the next three years, I would like to present you with this chairman's gavel, which reads, "W. D. Kirkpatrick, Chairman, Committee 20, 1955–1957." (Applause).

Vice Chairman Kirkpatrick: Thank you, sir.

President Miller: Mr. Kirkpatrick, your committee is now dismissed with the thanks of the Association.

The unofficial registration as of 4 pm today is 1523 members and guests, compared with 1383 last year—an increase of 140—so it looks as though we are headed for another record.

The last committee to report to us today is Committee 11—Records and Accounts. The chairman of this committee is Mr. H. N. Halper, valuation engineer, Erie Railroad, at Cleveland. I shall appreciate it if Mr. Halper, the committee vice chairman and secretary, and the various subcommittee chairmen, will take their places at the high-level platform. All other members of your committee may be seated at the committee table at the lower level.

Mr. Halper, you may proceed as soon as you are ready.

Discussion on Records and Accounts

(For report, see pp. 649–674.)

(President G. W. Miller presiding.)

Chairman H. N. Halper (Erie): Mr. President, members of the Association and guests: Before proceeding with the presentation of our report, Committee 11 wishes to express its deep sorrow at the passing—on March 9 of this year—of our esteemed member, Mr. C. Jacoby, valuation engineer of the Southern Railway System. A suitable memoir will be prepared and presented as part of our next committee report.

Chairman Halper: Your committee has worked through the year on all of its eight assignments, both by correspondence and at four meetings attended by a large portion of our members. At one of our meetings, in Cincinnatio, Ohio, we held a brief joint session with several members of Subcommittee 3 of Committee 16, studying the fluctuation of maintenance-of-way expenses in relation to change in traffic density. Mr. J. P. Ray, regional engineer, Baltimore & Ohio Railroad, and his subcommittee have done a great deal of exceptionally fine work on the subject. We propose to hold another meeting with his subcommittee to render whatever assistance we can in its arduous undertaking.

I should like to note here that the great honor of Member Emeritus has been bestowed upon three members of our committee—Messrs. C. C. Haire, of the Illinois Central, J. H. Hande of the Baltimore and Ohio Railroad, and B. A. Bertenshaw of the New York Central System. The members of this committee congratulate these men upon the honor received, and wish to express here our appreciation of the faithful and diligent work they have done for Committee 11, as well as for the Association.

The report of Committee 11 is printed in Bulletin 520, pages 649 to 674. I should like to call your attention to a special report entitled, Joint Projects and Joint Facilities, beginning on page 669. From time to time this committee, in addition to its regular assignments, requests one of its members specially qualified to prepare an informal talk or paper on a subject of particular interest to the membership. Mr. William S. Gates, Jr., assistant to auditor-valuation, Chicago & Illinois Midland Railroad, presented such a paper to us at our meeting in New Orleans on January 13, 1954. The above report is a condensation of his paper.

In the absence of Mr. M. A. Bryant, chairman of Subcommittee 1, his report will be presented by Mr. W. M. Ludolph, assistant engineer, Milwaukee Road.

Assignment 1—Revision of Manual, was presented by W. M. Ludolph (Milwaukee Road) in the absence of Subcommittee Chairman M. A. Bryant (Missouri Pacific).

Mr. Ludolph: Your committee submits the following report of progress in further revision of the AREA Manual of Recommended Practice.

The revision of Graphical Symbols, Figs. 1 to 8, incl., appearing on pages 11–4–11 to 11–4–18, incl., has been completed by a special joint committee consisting of two members of this committee and two members of Committee V of the Signal Section, AAR, operating as American Standards Association Subcommittee 1–ASA–Y–32.1.

In addition, ASA Subcommittee 1 made revisions in American Standard Graphical Symbols for Railroad Use, ASA Z32.25, coordinating all revisions with those made in AREA Graphical Symbols. Revisions were submitted to Allen F. Pomeroy, chairman, Y–32 Advisory Group, ASA, on September 20, 1954, for review of his group, and all other committees of ASA. This may take a year, but since any further revision may affect the AREA symbols under study it is recommended that revision of Figs. 1 to 8, incl., pages 11–4–11 to 11–4–18, incl., be deferred until final approval by ASA.

President Miller: Thank you, Mr. Ludolph. Your report will be so received.

Chairman Halper: Subcommittee Chairman A. H. Meyers assistant engineer—valuation, Texas & Pacific Railway, will report on Assignment 2.

Assignment 2—Bibliography on Subjects Pertaining to Records and Accounts, was presented by Subcommittee Chairman A. H. Meyers (Texas & Pacific).

Mr. Meyers: Your committee presents a bibliography of subjects pertaining to railroad records and accounts for the period September 1953, to September 1954, both inclusive, consisting of 52 articles considered worthy of note by your committee.

This report is submitted as information.

The inclusion of an article in this bibliography does not constitute an endorsement of the individual article.

President Miller: Thank you, Mr. Meyers.

Is there any discussion in connection with this bibliography?

Chairman Halper: Subcommittee Chairman W. M. Ludolph, assistant engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, will report on Assignment 3.

Assignment 3—Office and Drafting Practices, was presented by Subcommittee Chairman W. M. Ludolph (Milwaukee Road).

Mr. Ludolph: This is a progress report, submitted as information. It deals first with an improved tracing cloth, and, second, with Association of American Railroads participation in the work of American Standards Association Sectional Committee Y.14 in preparing the "American Drafting Standards Manual", and American Standards Association Committee Y.32 in the revision of American Standard Z.32.2.5 "Graphical Symbols for Railroad Use".

Since our report was submitted, the revised draft of the Standard Z.32.2.5 was returned by the advisory group of American Standards Association Committee Y.14 to the task group, with suggestion for further revision of the standard.

The task group met again on December 14, 1954, to consider these suggestions and made certain changes in the proposed revision of the standard. These consisted principally in the arrangement of the order of the symbols.

It is expected that revised drawings for the proposed revision of the standard will be submitted to the advisory group of American Standards Association Committee Y.32 shortly.

President Miller: Thank you, Mr. Ludolph. Is it your intention to have this material prepared in form for submission and approval for inclusion in the Manual in another year or so?

Mr. Ludolph: It is our intention to get this material in the Manual as soon as possible. There will be a few cases where there will be some revision. For example, the Signal Section symbols for crossing gates, and so forth, differed from the AREA, and we are recommending changes in the AREA Manual accordingly. In another case we have taken the matter up with the Signal Section for revision of their symbols for certain facilities.

President Miller: That is certainly a desirable procedure.

Chairman Halper: Subcommittee Chairman W. M. Hager, assistant valuation engineer of the Southern Railway System, will report on Assignment 4.

Assignment 4—Use of Statistics in Railway Engineering, was presented by Subcommittee Chairman W. M. Hager (Southern).

Mr. Hager: This year your subcommittee submits as information progress reports on its two uncompleted assignments, namely:

Assignment 4–b—Standard Costs Developed by Statistical Methods, and Assignment 4–d—Budgetary Procedures.

Each of these assignments is under the control of a section chairman, following the pattern for organization adopted by the subcommittee.

A great deal of effort has been devoted to the collection and study of information pertinent to Assignment 4–d, Budgetary Procedures. Results are beginning to materialize.

The initial draft of a report, which will embrace the better practices and methods in use, is being prepared for the first critical review and study by the full committee. The final report on this assignment should be ready for submission to the Association at its next annual meeting.

The report on Assignment 4–b, Standard Costs Developed by Statistical Methods, will be presented by Section Chairman L. W. Howard, assistant land and tax commissioner, Chicago and Western Indiana Railroad Company.

L. W. Howard (Chicago & Western Indiana): This year this subsection of Subcommittee 4 submits a progress report on continuing Assignment 4–b.

The main effort during the past working season was directed toward development of a simplified method of obtaining a large volume of operating data for any individual machine or individual work operation. The method reported on produces such a volume of information in a short time and permits the obtainment of data through the use of minimum manpower and at minimum cost.

The subsection has obtained data covering all individual work operations necessary in a rail laying organization, and is now engaged in directing its efforts toward the combination of the individual work units in such a manner as to produce gang sizes for different desired results.

This is a progress report, submitted as information, and your subcommittee recommends continuation of the study.

President Miller: Thank you, Mr. Howard. Your report will be received as information.

Chairman Halper: Is there any discussion of Mr. Howard's report?

T. M. von Sprecken (Southern): Is it possible to determine the relative efficiency of the maintenance of two railroads by comparing the standard costs developed by them?

Mr. Howard: Mr. von Sprecken, I don't believe this committee feels that it is possible to make a comparison on the basis of the standard costs such as we are developing. We have found during our studies that standard costs vary greatly, even from mile to mile on any one railroad, and surely from division to division on such railroad.

We think we would have a comparative value only if one railroad was exactly like another railroad. That is, were their forces mechanized? Were the two railroads mechanized to the same extent? Did they maintain their equipment to the same extent? Was the ratio of their mileages approximately the same, and divided as between single track, double track, multiple track, yard track, sidings, and so forth? Is their traffic the same? Is the topography of the country through which they operate the same? Are their climatic conditions the same?

I think the committee recognizes that no two railroads could be found with all of these factors the same, and I have listed only a few of them. We have directed our study toward developing costs so that a railroad, within itself, can determine the best methods of organizing its own work.

In connection with this, in previous years this subcommittee published—in the Proceedings, and as Manual material—recommended methods of making comparisons of railroads, and all those methods, to date, go back to the basic accounting of costs.

Mr. von Sprecken: Thank you, Mr. Howard.

President Miller: Is there any further discussion?

Chairman Halper: Subcommittee Chairman H. T. Bradley, valuation engineer of the Missouri Pacific Lines, will report on Assignment 6.

Assignment 6—Valuation and Depreciation, (a) Current Developments in Connection with Regulatory Bodies and Courts, was presented by Subcommittee Chairman H. T. Bradley (Missouri Pacific).

Mr. Bradley: One of the items mentioned in the report of this subcommittee was the publication of Elements of Value, as of January 1, 1953, by the Bureau of Accounts, Cost Finding and Valuation, Interstate Commerce Commission, which was released March 1, 1954.

On March 4, 1955, the same bureau issued a similar report, showing standard elements of value for Class I line-haul carriers as of January 1, 1954. The document is a 24-page statement, with an explanation of methods employed on pages 22–24, incl. Elements of value are shown by individual roads and by regions and districts.

A comparison of this report with the one of January 1, 1953, indicates for the country as a whole an increase of about 2 percent in original cost, and an increase of 12 percent in the cost of reproduction, new, and cost of reproduction less depreciation.

Actually, railroad construction costs increased only about 4 percent during this period. The remaining increase is due to a revision of the so-called period price level used in making these estimates. As of January 1, 1953, period prices were approximately 23 percent below spot prices for 1952, whereas, in the present issue, period prices are only 18 percent below prices for 1953. Apparently this was done on the theory that present-day prices will remain in effect for a long time to come, or at least the chances of going back to pre-World War II levels are very remote.

Values assigned to land are virtually unchanged. Working capital decreased $20,000,000.

This report is submitted as information only.

President Miller: Thank you, Mr. Bradley. It will be received as information.

Chairman Halper: Is there any discussion of Mr. Bradley's report?

J. P. Morrissey (Erie): Since main line charges are affected by the depreciation accruals on new property constructed, after the project is physically completed, how do these accruals start, on account of such projects?

Mr. Bradley: Your question seems to call for a double-barreled answer, in that we maintain depreciation records both for the Interstate Commerce Commission and the Internal Revenue Service.

Answering the first part of the question, which would be in conformity with the ICC rules, a project is eligible for inclusion in the depreciation base as the cost is reported under the provisions of Order No. 3, as prescribed by the commission.

Such costs are not usually available during the month following the completion of the work. One expedient is to estimate the cost of the work and then, when the completion report is made, to adjust the cost to the true cost. Retirement would follow the same general rule, except that I would say that in the case of branch line abandonments authorized by the commission, the effective date of abandonment would be the governing date, and not the actual date of demolition.

With respect to the IRS, under which we pay our income taxes depreciation accruals are handled on a yearly basis. In other words, the depreciation base is determined as of the beginning of the year and as of the end of the year, and a simple average of the two figures taken. This method results in assuming that all additions and betterments completed during any given year were in service for six months.

Mr. Morrissey: Thank you, Mr. Bradley.

Chairman Halper: Subcommittee Chairman W. S. Gates, Jr., assistant to auditor—valuation, Chicago & Illinois Midland Railroad, will report on Assignment 5.

Assignment 5—Construction Reports and Property Records, was presented by Subcommittee Chairman W. S. Gates, Jr. (Chicago & Illinois Midland).

Mr. Gates: You will note that our report this year is a progress report. It is the hope of the subcommittee that we shall complete this study this year and publish a final report which will include procedure to be followed in producing a B.V. 588 return with a tabulating machine. The B.V. 588 report is a system completion report of construction programs of each railroad for the preceding year, filed annually with the Interstate Commerce Commission Bureau of Accounts, Cost Finding and Valuation. These reports form the basis for the detailed property records of each railroad.

President Miller: Thank you, Mr. Gates.

Chairman Halper: Is there any discussion on Mr. Gates' report?

Fred N. Nye (New York Central): What use do engineers make of the property reports, and is their use sufficiently important to justify the cost of preparation?

Mr. Gates: I am most happy to answer that question. The expense of maintaining the railroad property records through the use of the B. V. 588 returns is more than justified by their extensive use.

Mr. B. H. Moore's monograph, entitled "The Federal Valuation of Railroads in the United States, reprinted from AREA Bulletin 503, and available at 50 cents per copy from the AREA secretary, gives a list, on pages 43 to 46, incl., of some 49 different uses by either the government or the railroads.

For instance, it is used for current cost data, producing construction indices and annual guide prices. It assists in passing upon proposed railway organization plans, loans, security issues, and refinancing proposals. It helps in the determination of past accrued depreciation and reorganized or consolidated railroads. It is used to protect the company's interest in tax matters. It forms the basis for insurance schedules. It forms the basic data in the preparation of a rate base required by the various public utility commissions when application is made by the railroads for increases in passenger suburban fares. It helps to arrive at proper rentals to be paid or charged for the use of railroad property. It is used to give estimates of value assigned to trackage rights.

I could continue on at some length, but time will not permit. Mr. Moore's monograph gives the full details. You will find it very interesting reading.

As a final comment, I wish to add that the valuation records are the only records available where the details of the physical property owned or used by your company are set forth in a useable style.

President Miller: Thank you, Mr. Gates.

Chairman Halper: The report on Assignment 7 will be presented by Subcommittee Chairman M. Friedman, chief valuation engineer of the New York Central System.

Assignment 7—Revisions and Interpretations of ICC Accounting Classifications, was presented by Subcommittee Chairman M. Friedman (New York Central).

Mr. Friedman: Your subcommittee has made several progress reports relative to the status of ICC Subject 439, "Units of Property and Other Related Matters". This subject was originally submitted to the Accounting Division of the Association of American Railroads by the Bureau of Accounts and Cost Finding of the ICC on July 31, 1951. It proposed certain revisions of the instructions relating to the accounting classification and also prescribed a list of units for the depreciable road and equipment accounts, the cost of which should be written out of the investment accounts when such units are retired and replaced. The accounting division recognized the importance of the subject as an engineering as well as an accounting matter; and appointed a working committee consisting of engineers and accountants to study the subject and recommend changes in the ICC proposals that would eliminate the objectionable features and would be acceptable to the railroads. The four engineers appointed to the working committee are members of this Association and its Committee 11.

The working committee and the subcommittee of the AAR Accounting Division held several meetings among themselves and conferences with representativs of the ICC Bureau of Accounts, Cost Finding and Valuation, at which various differences between the original ICC proposals and the railroad recommendations were discussed. The membership of Committee 11 was currently advised at all of its meetings of progress made in these conferences, and the Committee 11 reports to this Association during the period of the negotiations also referred to the developments in the matter.

As a result of the conferences, the ICC Bureau of Accounts, Cost Finding and Valuation submitted a revised proposal dated May 20, 1954, which is considered satisfactory to the railroad representatives. Your subcommittee advised Committee 11 of this development, and after discussion of the revised proposal, the committee adopted a resolution approving the actions of the working committee and so advised the AREA Board of Direction.

The revised proposal modifies the Uniform System of Accounts as follows:

(a) Prescribes a list of accounting units to designate those items of property in the depreciable road and equipment accounts, the cost of which shall be written out of the property accounts when the property is retired and replaced.

(b) Adds instructions for the accounting to be followed relating to "changes in line of road" and "relocations of yard tracks".

(c) Adds a "major renewal rule" applicable to roadway facilities and equipment and instructions for the accounting relative thereto.

We are advised that the proposal dated May 20, 1954, was circulated among the members of the AAR General Committee of the Accounting Division and that it was approved by a majority of that committee.

The ICC issued a notice to all railroad companies, dated October 12, 1954, advising that its Division 1 had approved the modifications to the accounting procedure outlined above. The changes in the accounting rules and the list of units attached to the notice are identical with those in the proposal dated May 20, 1954. The notice required that any objections to the modifications must be filed on or before Nov. 22, 1954. On Nov. 24, 1954, the ICC issued the order making these modifications effective Jan. 1, 1955. The order is included in Amendment No. 4 to the AAR publication of the Uniform System of Accounts for Railroad Companies.

No other changes in the Uniform System of Accounts, or of its interpretations, that are of interest to engineers have been made since the last report of your subcommittee.

This report is presented as information only.

President Miller: Thank you, Mr. Friedman. It will be so received.

Chairman Halper: Is there any discussion on Mr. Friedman's report?

W. R. Swatosh (Erie): To what extent, if any, will expenses, such as indicated by way of ICC order of November 24, 1954, be effective?

Mr. Friedman: Mr. Swatosh, the analysis of this order and the application of it possibly will affect operating expenses. However, the points involved in the discussion of this question depend on the accounting practices heretofore followed by your railroad.

In connection with changes in line of road, relocation of yard tracks, and replacement of depreciable road and equipment property, these practices must have been different on the various railroads, because the primary reason for the revised instructions was to prescribe uniform handling of the accounting for such property changes.

The new instructions applying to changes in line of road require that the cost of the new line be written out into the investment accounts, and the cost of the abandoned line written out therefrom may have the effect of decreasing charges to operating expenses.

Relocations of tracks within a yard, involving the dismantling as well as the shifting of the tracks, are chargeable to operating expenses under the new instructions. If your practice was to retire the cost of the dismantled tracks and to write in the cost of the tracks which replaced them, your charge to operating expenses will be increased.

The application of the major renewal rule to replacement of units of road property may tend to increase operating expenses, for the reason that those units where the replacement cost is under $35,000 are exempt from the rule. Such units are considerably more numerous than higher-valued ones, and you may renew them except for complete replacement, and charge the cost to operating expenses.

In the event that extensive replacement or renewals are to be made to a unit of road property, the replacement cost of which exceeds $35,000, you must make the test required in instructions to determine whether the unit shall be classified as rebuilt, under the provisions of the major renewal rule, or whether the cost may be charged to operating expenses.

R. C. Rankin (St. Louis–Southwestern): Under the new order, how would you account for the driving of a timber trestle where only piling and caps are replaced, and the deck is not disturbed, other than shifting?

Mr. Friedman: That question also depends upon the considerations that may influence the answer. In other words, was the reason for your replacement a relocation of line, or was it simply a shifting of the trestle due to operating conditions? I believe that the major renewal rule would probably apply in your particular case, because if the cost of the entire unit, the entire trestle, exceeded $35,000, you must apply the test to determine whether more than 50 percent of the reproduction cost or replacement cost of that complete unit was involved in the replacement of your piles and caps.

Ordinarily, I should say that ordinary shifting of a track in connection with the rebuilding of a trestle, or reconstruction, as you say, in connection with the relocation of a line, would be a rebuilding job, and with the job of rebuilding I believe we should apply the major renewal rule, and retire the cost of the old trestle and reinstall it at the secondhand value of the material reused, plus the cost of additional labor and material, to bring it up to standard form.

Mr. Rankin: Thank you.

President Miller: Thank you, Mr. Friedman.

Chairman Halper: Our last assignment is No. 8, on simplification of records, and Subcommittee Chairman L. W. Howard, assistant land and tax commissioner, Chicago & Western Indiana Railroad, will present this report.

Assignment 8—Simplification of Records to Determine Original Costs of Tracks to Be Used in Their Retirements From the Investment Account, was presented by Subcommittee Chairman L. W. Howard (Chicago & Western Indiana).

Mr. Howard: Since publishing our progress report in Bulletin 520, your subcommittee has been divided into two subsections:

Subsection 8–a has been given the assignment to develop methods to determine average costs to be used for track retirements.

It is circularizing its members for suggestions as to procedures to follow, and desired goal, after which definite plans for pursuing the study will be formulated.

Subsection 8–b has been given the assignment to outline a procedure whereby a carrier, which does not now have a record for each mile of main track and individual side tracks, can most economically create such a record.

This subsection has collected data for developing its report and will continue its study and should make a final report during the coming year.

Your subcommittee submits this report as progress and recommends the subject be continued.

President Miller: Thank you, Mr. Howard. Your report will be received as information.

Chairman Halper: This completes the report of Committee 11.

President Miller: Mr. Halper, your committee continues to present interesting and valuable reports to this Association. This year is no exception. We are greatly indebted to you and your committee for the valuable work which you do in our behalf, in keeping us up to date with respect to all matters relating to accounts and records. I am sure all of us here will agree that the accounting records which an engineer has to keep are certainly a big problem, and it is most difficult to keep up to date on current changes.

Mr. Halper, your committee is now excused with the thanks of the Association, and the meeting will stand recessed to reconvene tomorrow morning at 9 am in the Red Lacquer Room.

(The meeting recessed at 5:05 o'clock.)

Morning Session—March 16, 1955

(The meeting was reconvened at 9:00 o'clock, in the Red Lacquer Room, President G. W. Miller presiding.)

Presdent Miller: Will the meeting please come to order? We have a long and interesting program this morning, and I hope that we can expedite it as much as possible in order that we may adjourn on time for our annual luncheon at 12 noon. On the other hand, on behalf of the committees reporting, I do invite the audience to comment on or criticize any of the individual reports, in the interest of making our Proceedings as complete and as valuable as possible.

(Annonuncement on use of portable microphones.)

President Miller: The first committee to report this morning is Committee 24—

Cooperative Relations with Universities. The chairman of this committee is Mr. R. J. Stone, vice president operations, St. Louis–San Francisco Railway, St. Louis.

Mr. Stone, will you and members of your committee please come to the platform and present your report?

Discussion on Cooperative Relations with Universities

(For report, see pp. 565–587.)

(President G. W. Miller presiding.)

Chairman R. J. Stone (St. Louis–San Francisco): Mr. President and gentlemen, your Committee 24 reports on each of its four current assignments, and in addition it is privileged to submit a special report by one of its members and a former AREA president, Mr. C. G. Grove, covering the annual meeting of the American Society for Engineering Education at the University of Illinois on June 14–18, 1954.

Probably the most outstanding accomplishment of Committee 24 during 1954—and one for which our Subcommittee 4, under the chairmanship of Mr. G. A. Kellow, is due a great deal of credit—is the completion of the drafting of the text of a proposed brochure entitled The Railroad Field—A Challenge and Opportunity for Young Engineers, to be published for distribution to college undergraduates, with a view to attracting to the railroad industry additional graduate engineers with the aptitudes and specialized training needed in the road-building and maintenance of way, signaling, communications, mechanical, electrical, research, and other departments of the railroads, to protect their $32,000,000,000 investment.

Not only are engineering graduates desired by the railroads for their specialized training, but for development as future executives as well, many of our railroad presidents having had engineering training and experience, and practically every major railroad in the country having men with such a background in various executive positions.

In addition to opportunities for advancement afforded young engineers, the railroads offer attractive compensation, a high degree of job security, various desirable so-called fringe benefits, and, in many instances, on-the-job training courses. An AREA study has shown that the average starting salary paid engineering graduates by the railroads is in line with or slightly above that paid by industry generally, and the minimum is well above that reported for all university graduates.

In addition to regular on-the-job training courses, one means used by some of the railroads to encourage promising technical talent to enter the industry is to provide opportunity for student engineers to work on a part-time or vacation basis in various departments, to expand their practical knowledge of railroad operations coincidental with their academic training.

Mr. Grove and our four subcommittee chairmen will each highlight their respective reports which are printed in full in Bulletin 520, for January 1955.

I will call on Mr. Grove for his remarks on his special report, first.

C. G. Grove (Pennsylvania): Mr. Stone, Mr. President: Those of your who attended the sessions yesterday, I'm sure, noticed the emphasis placed upon the necessity for this Association's securing more Junior Members in order that they might grow up with the organization and become leaders in the AREA in the future. The number of junior engineers that we have as members has not been increasing, and, therefore, deserves some attention.

This committee has several avenues which it may use to help in interesting college students to affiliate themselves with the railroads. The American Society for Engineering Education, which is made up of the deans and professors and instructors of the schools of engineering all over our country, is one of the avenues that we are trying to work through in order to better the situation.

The Association of American Railroads, of which we are a part, has seen fit to take out a membership, an Industrial Membership, in the Society for Engineering Education, and I have had the good fortune of being selected to represent the AAR and to attend the Society's annual meetings, keeping in contact with the schools as to their curriculums and other items that would be advantageous in getting in touch with students who might be interested in the railroad profession.

A report on the last meeting of the Society, which was held at the University of Illinois, is in the Bulletin, as indicated previously. This meeting was very interesting, and I am sure it was helpful to talk to these professors, and to other members of the Society who represent industry, to get their viewpoints in their endeavor to provide the proper instructions for young men who may go into their fields of work. The same applies to the railroads.

The next meeting of the Society will be held at Penn State this year, and I do not feel that attending it will be a very difficult assignment because that is where I was educated. I look forward to going back, not only to the school, but also to the annual meeting, and again having the pleasure of mingling with the industrial representatives as well as the representatives of the schools.

I am sure that while we are not going to be able to make our influence felt very much immediately, over a term of years it will be beneficial and helpful to the railroad industry to get young men who will come and work for us.

Chairman Stone: May I ask if there are questions or comments concerning this report?

The assignment of Subcommittee 1 is to stimulate greater appreciation on the part of railway managements in hiring and training selected graduates. Mr. D. V. Tilman, senior assistant engineer, Baltimore & Ohio Railroad, subcommittee chairman, will report.

Assignment 1—Stimulate Greater Appreciation on the Part of Railway Management of:

(a) the importance of bringing into the service selected graduates of colleges and universities, and

(b) the necessity for providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement,

was presented by Subcommittee Chairman D. W. Tilman (Baltimore & Ohio).

Mr. Tilman: The objective of Subcommittee 1 is to stimulate greater appreciation on the part of railway management of the importance of bringing into the service selected graduates of colleges and universities, and the necessity for providing adequate means for recruiting such graduates and of retaining them in the service by establishing suitable programs for training and advancement.

The report of this subcommittee has been published in the Bulletin. It is a summary of a report resulting from a research survey made by the Professional Engineers Conference Board for Industry, with the cooperation of the National Society of Professional Engineers. The report is entitled, How to Attract and Hold Engineering Talent. If you have not read this summary, you are urged to do so; for those of you who may wish to read the complete report, copies may be obtained from the Professional Engineers Conference Board for Industry, at Washington, D. C.

Your subcommittee presented a progress report to this convention in 1953, in which it was concluded that the problem of recruiting and retaining technically qualified men could possibly be solved by the technical personnel of each railroad. We should all make sure that no opportunity is overlooked to emphasize to our management the importance of this problem. Thank you.

Chairman Stone: May I ask if there are any questions?

The assignment of Subcommittee 2 is to stimulate a greater interest among college and university students in the science of transportation. Dean R. P. Davis of the College of Engineering of West Virginia University, and chairman of the subcommittee, will report.

Assignment 2—Stimulate Among College and University Students a Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure by Cooperating with and Contributing to the Activities of Student Organizations in Colleges and Universities, was presented by Subcommittee Chairman R. P. Davis (West Virginia University).

Dean Davis: Fifteen years ago, Committee 24—Cooperative Relations with Universities, was set up to do a certain job. I quote from the first annual report of this committee—Proceedings, Vol. 42, page 157:

"Your committee understands that, in re-establishing this committee, the Board of Direction of this Association had in mind the importance of (a) bringing about the education of a capable group of young men in the railway problems of today and the days that are ahead, and (b) providing for these men opportunities in the various branches of railway service comparable with those presented by other industries."

Part (a)—bringing about the education of a capable group of young men—is the objective of those of our Committee 24 responsible for carrying out Assignment 2. However, this assignment has been broadened somewhat over the years since 1941, and we are now charged with the duty of Stimulating Among College and University Students a Greater Interest in the Science of Transportation and Its Importance in the National Economic Structure.

I think that it is fair to say that between the two world wars interest in railroading as a career fell to a new low on the part of both engineering students and engineering college faculties. This was due partly to low salaries on the railroads, and partly to the general notion that the caste system made it difficult to secure advancement except through seniority. There was also the belief that, by and large, railroad management was not as progressive as that in other industries.

We have come a long way in these 15 years in creating a better atmosphere toward the railroads in the engineering schools. Starting salaries on the railroads now compare favorably with those elsewhere. Many railroads have shown that the young engineer can advance on the basis of ability rather than years of service.

We like to think that Committee 24 has had some part in creating this better understanding. In the report of our subcommittee we have listed typical contacts made by members of Committee 24 with many of our educational institutions. These contacts may be in the form of talks before student groups by railroad representatives, visits by groups of engineering students to scenes of railroad activities, and the holding of seminars. A good example of a successful seminar is the one entitled, Railroad Management—The Next Generation, held at the University of Michigan on February 10 and 11, 1954. Three members of Committee 24 participated in this seminar.

In closing, your subcommittee wishes to point out the fact that the potential contribution of the Association, with its membership of well over 3000 individuals, is vastly greater than the possible contributions of any committee in stimulating a greater interest in transportation engineering among our college students. We therefore bespeak your continued interest in the work of our committee, and trust that individually, and in groups, you will avail yourselves of opportunities to contact student groups.

Chairman Stone: Thank you, Dean Davis.

The assignment of Subcommittee 3, The Cooperative System of Education, Including Summer Employment in Railway Service, will be reported on by Subcommittee Chairman O. W. Eshbach, professor of engineering science, Northwestern Technological Institute.

Assignment 3—The Cooperative System of Education, Including Summer Employment in Railway Service, was presented by Subcommittee Chairman O. W. Eshbach (Northwestern University).

Mr. Eshbach: The report of the subcommittee is published in the January Bulletin, No. 520. It contains quite a few statistics, which I will not repeat, except that I would like to comment on the reason for it.

The report is a high spot of a 3 to 4-year study, taking some of the pertinent facts that pertain to engineering education in the United States.

First, I would like to say why the study was conducted. Some 5 or 6 years ago, at the close of World War II, there was considerable concern over the balance of supply and demand. Later, in urgent situations, the drainage of special talent into the armed forces was felt, as those men were needed elsewhere. The government considered the situation in its relation to universal military training and how that might affect the schools; it was general knowledge that during the early part of the war, the birth rate had increased, and it was known that there would be an increase later on in the supply of people.

Following a request for cooperation by the United States Government, a study was started by the Joint Engineers Council, known as the Manpower Commission. This commission is still in existence. When President Eisenhower was president of Columbia University, he was interested in the study. Through the Ford Foundation, money was contributed, and a study was conducted which was perhaps more subjective than objective, because of the difficulty and costly nature of obtaining the data.

That report was published about 2 years ago. Before it was published, and while it was in progress—realizing what the outcome might be, and that there was need for more definite data—four of the prominent national professional societies, through a joint committee, made a study, subsidized by the Rockefeller Foundation, to determine whether it was important enough to carry on an investigation of this type. They decided it was, and in the next 3 years close to $300,000 was spent in this investigation.

Among the pertinent things that came out of the investigation was the feeling that there was need to feel some concern about the supply of all professional or specialized talent in our country from the youth groups as they were coming along. The concern was not so much just with pure numbers, but the percentage of those who were getting the preparation, after entering college, to enter into the various professions, to maintain the society which we have built.

The scientists and engineers were perhaps most vocal, but in the study it was shown that similar situations existed in many other areas. This was particularly true, of course, in the area of public school education and the supply of teachers, the supply of nurses, the turnover of which has always been and always will be heavy.

This report was supposed to be published last year; it came out at the end of the year. Your committee, working with two of the three groups, made available to about 40 of the railroad companies—through their membership on Committee 24—a copy of this report, with the idea that as time goes on you will hear more and more about the problems of education, about the public's responsibility for public education, and the private school problem versus the state-supported school problem. With the report you will have at your disposal the best information that is available.

That was the activity of your committee for this year. I will leave the report with you at that point.

Chairman Stone: Thank you, Dean Eshbach.

Subcommittee Chairman G. A. Kellow, special representative of vice president, Chicago, Milwaukee, St. Paul & Pacific, will report on Assignment 4.

Assignment 4—Conduct a Study Looking to the Publication of a Booklet, or Booklets, for Distribution to Educational Groups, Particularly High Schools and Undergraduates in Colleges, Designed to Stimulate Interest in the Opportunities Afforded in a Railroad Engineering Career, Collaborating with the Mechanical Division, the Electrical Section, the Signal Section and the Communications Section, AAR, was presented by Subcommittee Chairman G. A. Kellow (Milwaukee Road).

Mr. Kellow: Your subcommittee, in this year's report, is submitting proposed text material to be included in a brochure to be designed primarily for undergraduates in colleges. It is intended that the text material presented be edited as necessary for inclusion in the brochure. With suitable photographs, an attractive and appealing publication should be available to support the railroads' efforts to obtain capable engineering graduates for future positions of responsibility in many departments.

The text material has been developed in cooperation with collaborating members from the Mechanical Division, the Electrical Section, the Signal Section, and the Communications Section, AAR. The School and College Service Section of the AAR Public Relations Department, through its manager, Dr. T. J. Sinclair, has assisted in many ways.

The committee recommends that the Board of Direction give consideration to the development of this material into an attractive brochure. The Public Relations Department of the AAR has prepared a preliminary dummy of a brochure and has obtained some estimates of cost. Both this department and our secretary's office have made preliminary studies on probable distribution of such a brochure. All of this work has been progressed to assist the Board of Direction in deciding on how to proceed further.

All of you have had an opportunity to review the suggested text published in Bulletin 520. Do you agree that there is need for the effort contemplated in this report? Do you feel that the material presented might well form the basis of an attractive brochure for discriminate distribution among the undergraduates of the engineering schools of the country? If so, would you change or modify it? Could it be made more effective?

The subcommittee, at this time, invites comments from the floor.

I would like to acknowledge all the time and effort our Association's secretary, Neal Howard, has contributed on behalf of the subcommittee. He has taken much more than a secretarial interest in this assignment and has assisted the subcommittee greatly.

This is a progress report, submitted as information.

Chairman Stone: Thank you, Mr. Kellow.

May I take this opportunity to thank these subcommittee chairmen and other members of the committee for these splendid reports, and also to express my personal appreciation to the committee for the high degree of cooperation they have shown in the work.

We are fortunate to include in our membership 14 representatives of colleges and universities, whose viewpoints and counsel are particularly beneficial.

Attention is directed to the meeting of Committee 24 to be held in Room 9 on the third floor immediately following the end of this report. It is hoped that all members will attend.

Thank you very much.

President Miller: Mr. Stone, when I was first employed by a railroad, the engineer of construction informed me that it cost $25,000 to train a man who was capable of locating a railroad. Since that time, maintenance problems have become more complicated, more expensive, and I am sure that any young engineer, after he is partly trained, is worth more than $25,000. So if your committee, in submitting this small brochure, which may cost a few thousand dollars, can assist even one railroad in securing one good man, it will have justified the effort put into it, and I am sure it will assist in securing many more than one man.

Your committee has rendered invaluable service on behalf of the railroads and this Association, and we are fortunate in the close contact which it gives us with the colleges and the universities, particularly through the representatives of those institutions on your committee. We are deeply indebted to each of them, and are glad that a number of them are with us today.

I am sure that the Board of Direction will give very careful consideration to your recommendation that your report, entitled, The Railroad Field—A Challenge and Opportunity for Young Engineers, be adapted into an attractive brochure for distribution to undergraduates in colleges and to others interested, either as an AREA project or in conjunction with the AAR.

I congratulate your committee on its new plan for holding two committee meetings each year, one at the headquarters of a railroad, which has given more than ordinary attention to the recruitment of young college graduates and their subsequent training, and the other on the campus of one of the colleges or universities represented on your committee.

Is there any discussion of the committee's reports; any questions?

If not, Mr. Stone, your committee is now excused with the thanks of the Association.

The next report to be brought before the Association is that of Committee 13—Water, Oil and Sanitation Services, of which Mr. H. L. McMullin, engineer of tests and water supply, Texas & Pacific Railway, Dallas, Tex., is chairman. Unfortunately, due to the illness of Mrs. McMullin, Chairman McMullin has found it impossible to attend our convention this year, so the report of Committee 13 will be presented under the direction of the vice chairman of the committee, Mr. H. M. Schudlich, engineer of water supply, Northern Pacific Railway. I shall be glad if Mr. Schudlich and the members of his committee will come to the platform and present their report.

Discussion on Water, Oil and Sanitation Services

(For report, see pp. 343–368.)

(President G. W. Miller presiding.)

Vice Chairman H. M. Schudlich (Northern Pacific): President Miller, members of the AREA, and guests: Before presenting the report of Committee 13, this committee records with sorrow the untimely death of Guy Emerson Martin, January 13, 1955. Mr. Martin, who was superintendent of water service of the Illinois Central Railroad, was a member of the AREA since 1942, and a member of Committee 13 since 1943. He was the senior past chairman of the committee.

MEMOIR

Guy Emerson Martin

Guy Emerson Martin, superintendent water service, Illinois Central Railroad, died on January 13, 1955, after an illness of several months. He is survived by his widow, Mildred Stegar Martin, and two children, Mary Bert, 15, and Guy E., Jr., 7.

Mr. Martin was born on December 9, 1898, in Princeton, Ky., the son of Willis M. and Mary Ingram Martin. He attended the Princeton public schools and the University of Kentucky.

In 1921 Mr. Martin entered the service of the Illinois Central as a water service helper at Princeton. In 1922 he was promoted to water service repairman, and in 1926 was further promoted to the position of supervisor of water service on the Gulf and Ship Island Railroad. In 1940 he was made supervisor bridges and buildings on the Kentucky Division of the Illinois Central, and in 1942 was promoted to superintendent water service, with headquarters at Chicago, the position he held at the time of his death.

Mr. Martin joined the American Railway Engineering Association in 1942, and in 1943 became a member of Committee 13, which now has the name Water, Oil and Sanitation Services. He took an active part in committee work and could always be counted upon to complete the task assigned to him. His zeal, coupled with kindly leadership, resulted in his appointment to the chairmanship of Committee 13 in 1951. He was also active on the Committee on Convention Arrangements and was vice chairman at the time of his death. He believed a great amount of benefit could be derived from membership in the Association and urged prospective members to join and take an active part.

Mr. Martin was also active in the American Railway Bridge & Building Association, which he joined in 1942. He was elected a director of that association in 1945, and became president in 1951. He was also a member of the American Water Works Association.

He was active in the affairs of the Woodlawn Baptist Church of Chicago, where, at the time of his death, he was chairman of the board of trustees, chairman of the finance committee, a deacon, and president of the men's Bible class.

Mr. Martin was kind, human and faithful. His associates will mourn his passing.

I would also like to mention that one of our retired members, Mr. E. M. Grime, former engineer of water service of the Northern Pacific Railway, has been elected Member Emeritus of the committee this past year. Our committee has been most pleased to confer this coveted honor upon Mr. Grime, who was a faithful and valued worker for 33 years.

Will you stand, please, Mr. Grime, so that we may recognize you?

Your committee has had nine subjects assigned for study during the past year. The reports are found in Bulletin 518, beginning on page 343.

The revision of the Manual has been very well done by Chairman McMullin, and there is no report at this time.

No report will be presented by Subcommittee 2—Types of Corrosion in Railway Water and Fuel Service.

Assignment 3—Federal and State Regulations Pertaining to Railway Sanitation, will be presented by the subcommittee chairman, Mr. H. W. Van Hovenberg, engineer of tests and sanitation, St. Louis Southwestern Railway.

Assignment 3—Federal and State Regulations Pertaining to Railway Sanitation, Collaborating with Joint Committee on Railway Sanitation, AAR, was presented by Subcommittee Chairman H. W. Van Hovenberg (St. Louis Southwestern).

Mr. Van Hovenberg (St. Louis–Southwestern): This is a progress report, presented as information. Your committee summarizes for this year the activities of the Joint Committee on Railway Sanitation, Association of American Railroads, composed of representatives of the Engineering and Mechanical Divisions, the Medical and Surgical Section, Operating Transportation Division, the United States Public Health Service, and the Department of National Health and Welfare of Canada.

The Joint Committee has continued its special subcommittee to supervise the activiites of the AAR Sanitation Research and Development, located at the AAR Research Center in Chicago, and has made recommendations for its maintenance and budget in 1955. Under the director and assistant director of this unit, studies have been progressed, principally with respect to phases of railroad sanitation bearing on potable water and water hydrants, waste disposal, food service, industrial cleaning chemicals, governmental regulations pertaining to railway sanitation, dining car refrigeration, and food handlers' training programs for dining car department personnel, along with visits to many AAR Member Roads to establish contact with officers who have been designated as responsible for sanitation matters within their respective organizations.

The Joint Committee has also continued to serve as liaison with the United States Public Health Service on aspects of sanitation related to railroad operations.

Your representatives on the Joint Committee are T. L. Hendrix, Jr., J. E. Wiggins, Jr., and H. W. Van Hovenberg, the last named serving also as the engineering representative on the special subcommittee.

If I may, I would like to ask the director of AAR Sanitation Research and Development, and the assistant director, respectively—Mr. Glynn and Mr. Reeves—to rise, that you gentlemen may know them when they do contact you in the future.

Is Mr. Reeves here?

This is Mr. Glynn on my left, gentlemen—the director of Sanitation Research and Development. Thank you, sir. (Applause).

Vice Chairman Schudlich: Thank you, Mr. Van Hovenberg.

Are there any comments from the floor on Mr. Van Hovenberg's report?

If there are none, we will proceed with the report of Subcommittee 4—Mechanics of Foaming and Carry-Over in Locomotive Boilers. There is no report on this subject at this time.

We will proceed with Assignment 5—New Developments in Water Conditioning for Diesel Locomotive Cooling Systems, Collaborating with Mechanical Division, AAR.

Assignment 5—New Developments in Water Conditioning for Diesel Locomotive Cooling Systems, Collaborating with Mechanical Division, AAR, was presented by Subcommittee Chairman M. A. Hanson, (engineer of research, Gulf, Mobile & Ohio).

Mr. Hanson: It is believed that approximately one-half of the railroads are now using borate-nitrite type cooling system inhibitors. The results obtained have been widely divergent, varying from excellent to completely unsatisfactory.

There have been a number of changes in the various formulations used. These relatively rapid changes have increased the difficulties in making valid evaluations of the results accomplished. However, the results to date are believed to justify the following conclusions.

1. Borate-nitrite inhibitors are less effective at reduced concentrations than alkaline chromate inhibitors.
2. The concentration of borate-nitrite inhibitors required for satisfactory inhibition is substantially double that required for alkaline chromates.
3. The borate-nitrite inhibitors have such limited solubility that considerable difficulty is experienced in applying them to the diesel engine cooling systems at the required concentrations.
4. The adoption of borate-nitrite inhibitors has been due to suspected skin irritations of employees handling alkaline chromates rather than any lack of effectiveness of alkaline chromate as corrosion inhibitors.
5. No complaints have been received concerning borate-nitrite inhibitors producing skin irritation.

Some question remains as to the effectiveness of borate-nitrite type inhibitors when used in waters containing substantial amounts of sodium chloride.

Limited tests are under way using soluble oils as corrosion inhibitors. Another test is under way using sodium molybdate. It is expected a report on these tests will be available during the coming year.

This is a progress report, submitted as information.

Vice Chairman Schudlich: Thank you, Mr. Hanson.

Are there any comments from the floor on Mr. Hanson's remarks and report?

If there are none, we will proceed with the report on Assignment 6—Railway Waste Disposal, to be presented by the subcommittee chairman, Mr. T. A. Tennyson, chief chemist, St. Louis Southwestern Railway.

Assignment 6—Railway Waste Disposal, Collaborating with Joint Committee on Railway Sanitation, AAR, was presented by Subcommittee Chairman T. A. Tennyson, Jr. (St. Louis–Southwestern).

Mr. Tennyson: This year your committee has made a review of the state and federal regulations pertaining to the disposal of industrial wastes as discussed in the various trade and technical magazines and by circulation of a questionnaire through Committee 13, AREA. Results of this activity indicate that all states now have water pollution control laws and organizations to enforce them, or operate in compliance with the Federal Water Pollution Control Act (Public Law 845—80th Congress). In addition to this, most of the major river basins and coastal areas are covered by interstate agreements concerning the control of pollution.

State, federal and the interstate regulations are of the type discussed in your committee's report published in the AREA Proceedings for 1950, and our present survey has indicated no basic changes since that time. This survey would also indicate that the railroads have no real waste disposal problem unless it is perhaps to continue the efficient operation of waste oil separation facilities which some railroads have had to install. Some limits currently prescribed for oil in individual situations have been 10, 15 and 20 parts per million. The laws generally do not set arbitrary limits on specific waste materials but forbid discharge which "shall cause or contribute to pollution of waters of the state."

An example is given by the definition of "unpolluted water or waste" established by Sanitation District No. 1, Campbell and Kenton Counties, Kentucky, which states that this "shall mean any water or waste containing none of the following: free or emulsified grease or oil; acid or alkali; phenols or other substances imparting taste or odor in receiving waters; toxic or poisonous substances in suspension, colloidal state or solution; and noxious or odorous gases. It shall contain not more than 10,000 parts per million by weight of dissolved solids, of which not more than 2,500 parts per million shall be as chloride, with permissible volume subject to review by the District; and not more than 10 parts per million each of suspended solids and B.O.D.". Some of the regulations do mention pH limits, which usually range between 6.0 and 8.5, although pH as high as 10.6 has been permitted. A complete list of the regulatory agencies and organizations concerned with water pollution control in the United States can be obtained from Subcommittee VII of ASTM Committee D–19.

This report is presented as information.

Vice Chairman Schudlich: Thank you, Mr. Tennyson.

Are there any comments on Mr. Tennyson's report?

If not, we will proceed with the next report, Treatment of Water for Cooling Purposes, a progress report, submitted as information by Subcommittee Chairman L. E. Talbot, chief chemist, Texas & Pacific Railway.

Assignment 7—Treatment of Water for Cooling Purposes, was presented by Subcommittee Chairman L. E. Talbot (Texas & Pacific).

Mr. Talbot: This is a report of progress, submitted as information.

The increased usage of air conditioning on the railroads in both rolling equipment and office buildings, and the increased use of the internal combustion engine during the past few years have introduced new problems in water treatment. This report outlines some of the problems being encountered and gives current methods of their solution. The problem of internal combustion engine cooling water treatment is handled under Assignment 5 of this committee.

There are three types of cooling systems, i.e., the once-through, the open recirculating, and the double recirculating. Each of these names is self-explanatory, and the type used is based on the problem of cooling encountered and the supply and quality of water available.

In the case of any cooling water, scale will be encountered. The types most frequently found are calcium carbonate, calcium sulfate, iron oxide and hydroxide, and mud and silica. Analysis of the supply water as well as the cooling water is necessary to determine the type of treatment required to give the best results.

In the majority of the cases of cooling, calcium carbonate is the type of scale encountered. Prediction of the tendency to deposit calcium carbonate scale is readily made by the use of the Langelier's equation (index). Where adjustment of the index is necessary, lime or soda ash is used to raise the index, while sulfuric acid is normally applied to reduce it. If a water is properly treated and sufficiently inhibited, no trouble should be encountered with encrustation, provided the saturation index is less than $+1.5$.

Also encountered in cooling is the problem of corrosion. There are numerous types of corrosion and as many methods for its prevention. Here again, water analysis is necessary as is the knowledge of the construction of the equipment.

As has been stated previously, each cooling problem has to be treated separately and then an application of one or more types of treatment applied to give the desired results.

Vice Chairman Schudlich: Thank you, Mr. Talbot.

With diesel operations becoming of major importance to the various railways, surely there must be some comment on Mr. Talbot's paper.

If there are none, we will proceed to Assignment 8—Diesel Oil and Water Servicing Facilities, to be presented by Mr. D. C. Teal, superintendent water supply, Chesapeake & Ohio Railway.

Assignment 8—Diesel Oil and Water Servicing Facilities, Collaborating with Mechanical Division, AAR, was presented by Subcommittee Chairman D. C. Teal (Chesapeake & Ohio).

Mr. Teal: The railroads have been more or less dieselized for years, and much study has been given and numerous reports made on the design, construction and operation of diesel fueling and watering facilities. Thus far, these reports have been presented in AREA Bulletins as information. However, it is felt that the research and experimental phase has now progressed to where standardization should be considered. Assignment 8 was made a year ago for the express purpose of reviewing and condensing previous committee reports and combining them with new material to form a statement of recommended practice that could be published in our Manual. The assignment also stipulated collaboration with other organizations.

We were unable to finish collaboration with other organizations in time to meet the publication deadline for Bulletin 518. The report is, therefore, presented to the Association at this time as information, with the understanding that a revised final version will be presented next year for inclusion in the Manual.

I would like to add that the collaboration with the Mechanical Division, and also with the Fire Protection and Insurance Section of the AAR, has since been accomplished, and that their approval in general, together with four or five suggested changes and additions, have now been received. These suggested changes will be carefully considered and probably all of them will be incorporated in the final version.

This is certainly not the time to review this matter in any detail. However, I would like to invite comments and criticisms from the floor of those who have reviewed this report, in order that all deserving ideas may receive proper consideration.

The report, as now presented, consists of two parts, one dealing with the design and construction of diesel fueling facilities, and the other with diesel watering facilities.

The report on Diesel Fueling Facilities, beginning on page 357 of Bulletin 518, has eight main sections, as follows:

Sec. A General Considerations
" B Fuel Oil Storage Facilities
" C Fuel Oil Pumping Facilities
" D Fuel Oil Distribution Lines
" E Unloading Facilities
" F Delivery to Locomotives
" G Fire Protection
" H Use of Low Grade Fuel Oil

The report on Diesel Watering Facilities starts on page 366 of Bulletin 518, and is composed of three main sections:

Sec. A Introduction
" B Diesel Cooling Water
" C Steam Generator Water

Are there any comments or suggestions on these reports?

This concludes the report of the subcommittee.

J. L. Goss (Northern Pacific): As to the report on Assignment 8, I would like to make one suggestion. Under item E, General, on page 362, I believe, attention should be called to the fact that some state laws prohibit the unloading from the bottom of tank cars on new installations. I believe that could be incorporated in the report.

Mr. Teal: Thank you, Mr. Goss. I assure you that your suggestion will be noted and recorded, and will receive our careful consideration.

As I said, the report is presented as information at this time. That concludes our report.

(Vice President Wm. J. Hedley assumed the chair.)

Vice President Hedley: Thank you, Mr. Teal.

Vice Chairman Schudlich: We will now have the report on Assignment 9—Disinfectants, Deodorants, Fumigants and Cleaning Materials, Collaborating with Joint Committee on Railway Sanitation, AAR. Mr. Glynn.

Assignment 9—Disinfectants, Deodorants, Fumigants and Cleaning Materials, Collaborating with Joint Committee on Railway Sanitation, AAR, was presented by R. S. Glynn, director, Sanitation Research and Development, AAR.

Mr. Glynn: A review of the subject material to be covered under Assignment 9 reveals each field to be sufficiently vast in scope to warrant individual consideration in reporting. Cleaners have been selected for the first of the series to be discussed, because of their importance in preparing the way for the application of one or more of the other materials being considered in this assignment.

The chemical industry has compounded hundreds of types of cleaners and preparations for use in cleaning, and the selection of a cleaner that will be appropriate for a given job represents a task of no small proportions. A survey of the railroad industry is being made to determine present practices in cleaning and the cleaning materials used. When this information is completed, a report will be made.

This is a progress report.

Vice Chairman Schudlich: Thank you, Mr. Glynn.

Are there any comments from the floor with regard to Mr. Glynn's paper?

There being none, we will conclude the reports of Committee 13. As I mentioned at the beginning of our presentation, Mr. Grime was elected a Member Emeritus of this committee. He was not here at that time, but I see that he is now here. Will you stand and be recognized, Mr. Grime? (Applause)

Mr. Chairman, this concludes the report of Committee 13.

E. M. Grime (Northern Pacific, retired): I appreciate very much the honor of being made a Member Emeritus. It's nice to be associated with Committee 13, even though I am not doing anything active now.

Vice Chairman Schudlich: After 33 years of service, Mr. Grime, you are entitled to this recognition.

Vice President Hedley: Thank you, Mr. Schudlich. Your committee has presented an outstanding series of valuable reports. It is interesting that this committee has expanded its field in recent years, keeping abreast of the times with an increasing number of reports dealing with fuel and sanitation services, all of which are valuable to the members of the Association.

Your committee is now excused with the thanks of the Association.

The next committee to report is Committee 7—Wood Bridges and Trestles. We will now hear a series of reports by the structural committees, of which this will be the first.

Mr. W. C. Howe, engineer of bridges and buildings, Bessemer & Lake Erie Railroad, Greenville, Pa., is chairman. Will Mr. Howe and the members of his committee come to the platform, please?

Discussion on Wood Bridges and Trestles

(For report, see pp. 635–648.)

(Vice President Wm. J. Hedley presiding.)

Chairman W. C. Howe (Bessemer & Lake Erie): President Miller, officers and members of the American Railway Engineering Association, and guests: Your committee reports on three of seven assignments, as published in Bulletin 510, January 1955, pages 635 to 648, incl.

Subcommittee Chairman R. E. Jacobus will present the report on Assignment 4—Methods of Fireproofing Wood Bridges and Trestles, Including Fire-Retardant Paints, a progress reports, submitted as information.

Subcommittee Chairman F. E. Schneider will present a final report, including specifications, submitted for adoption, on Assignment 5—Specifications for structural Glued Laminated Lumber.

Subcommittee Chairman W. A. Oliver will present a progress report, submitted as information, on Assignment 6—Design of Timber-Concrete Composite Docks.

At the conclusion of the report on each assignment, we will welcome your questions, comments, or criticisms.

Assignment 4—Methods of Fireproofing Wood Bridges and Trestles, Including Fire-Retardant Paints, Collaborating with Committee 17 and with the Fire Protection and Insurance Section, AAR, was presented by Subcommittee Chairman R. E. Jacobus, bridge and building supervisor, Illinois Central Railroad.

Mr. Jacobus: Under this assignment your committee, collaborating with the AAR research laboratory, is developing a satisfactory procedure for testing fire-retardant materials to be used on timber railroad bridges. With this information available to the industry, we hope to interest them in developing satisfactory fire-retardant products.

The 1955 program at the laboratory covers the testing and evaluation of commercially available materials.

This report is submitted as information. Are there any comments?

L. C. Collister (Santa Fe): Mr. Jacobus, you indicated that this information on laboratory techniques is available to the industry, but you don't give it to us in the Bulletin. We have done a lot of work on tests of fireproofing, of course, as you all know, and I'm wondering if we can get this laboratory burner technique so that we can correlate some of our preliminary work with the rest of industry?

Mr. Jacobus: I believe Mr. Coburn of the laboratory can answer that. Is Mr. Coburn available?

S. K. Coburn (AAR): The laboratory technique for evaluating coating materials has been in progress of development over the past two years.

Our most recent change of technique was just about two months ago, and one of the reasons for not publicizing the technique is because we have still been correlating some of the bits of information that we have with our earlier experiences. By the end of the year we hope to be able to finalize the technique and make it available.

Mr. Jacobus: Thank you, Mr. Coburn.

Vice President Hedley: Any other questions on this subject?

Thank you, Mr. Jacobus.

Assignment 5—Specifications for Structural Glued Laminated Lumber, Collaborating with Committee 6, was presented by Subcommittee Chairman F. E. Schneider (Santa Fe).

Mr. Schneider: Last year your committee presented, as information, a draft of

Specifications for Structural Glued Laminated Lumber, together with an appendix and tables of allowable stresses, and requested criticisms or suggested changes thereon.

Revisions of these specifications affecting only Arts. 1a and 11c have been recommended and approved by your committee.

Revision of Art. 1a was thought necessary to improve the description of glued laminated lumber. Revision to Art. 11c was necessary, as it is now possible to glue and laminate treated as well as untreated timber.

Material for the specification has been taken from several approved specifications, re-edited to AREA standards.

It is important to note that glues are available for exterior as well as interior use; also that this lumber can be pressure-treated successfully with present preservatives without de-lamination or harm to glue lines, or the lumber can be glued and laminated after treatment with some preservatives.

In view of the fact that the building industry already is using considerable glued laminated lumber, and since railroads are finding it more difficult every year to fill their bridge needs with full size timbers, we feel that it is urgent to have a specification for glued laminated lumber in our Manual.

Mr. Chairman, I move that these revised specifications be adopted and printed in the Manual.

Vice President Hedley: Is there a second?

W. R. Wilson (Santa Fe): What is the effect of the glue line on the admission of the treatment on these timbers, if you treat them after they are glued?

Mr. Schneider: It is a fact that the glue does stop some of the effectiveness of preservative treatment. In fact, we have revised our specifications to permit glueing and laminating after treatment. That overcomes this difficulty, but introduces other problems.

Mr. Chairman, I would like to call on Mr. Johnson, a member of our committee from the Forest Products Laboratory, to further answer this question. Mr. Johnson is very familiar with the studies that have been carried on at the Forest Products Laboratory in recent years on glue-laminating untreated as well as treated wood.

R. P. A. Johnson (Forest Products Laboratory): Mr. Chairman and members of the AREA: in answer to the specific question as to the effect of glue lines, the glue lines do have an inhibiting effect upon the penetration of preservatives. However, when you treat a glued-up laminated member, you have essentially the same type of protection that you get when you treat a solid member. In other words, you may have certain portions of the interior of it which are not penetrated, the same as you do in unglued members. The protection of the enveloping outside is, however, about the same.

There are certain things that you can do to facilitate the penetration. One of them is to put a thick soft wood lamination on the exterior. That will allow you to get complete penetration into the lamination; also to keep your end glue lines away from the edge, so as to give room on the sides for penetration. When that is done, you get essentially the same as you get in solid timbers.

However, it is important and essential that all fabricating, cleaning, and so forth, be done before the treatment is made. The glueing up of material which is treated before glueing presents a more difficult problem, and is one which requires a special technique. One of the objections to it is that a certain portion of the material has to be taken off and dressed down after treatment in order to get good contact surfaces, which removes a certain portion of the treated material. However, after you have the material properly dressed for glueing, and assuming the treatment is such that you don't have too much bleeding, then you have a timber which is penetrated practically throughout, and which can be cut, fabricated and handled after treatment.

Vice President Hedley: Thank you, Mr. Johnson.

Are there any further questions?

W. H. Miesse (New York Central): Do you have any information on the relative economy of laminated trestles with regard to railroad bridges over plain timber trestles?

Mr. Schneider: No, as yet we do not have such information. However, the committee is going to ask for an assignment next year on the design of structural glued laminated wood bridges and trestles, and we hope to come up with a recommended plan for better use of this new material.

Mr. Chairman, I would like to call on Mr. Newlin, a member of our committee from the Southern Railway. I understand he has made some studies on this problem. Perhaps he can look into his crystal ball and give us some idea of what we have to look forward to in the use of glued laminated lumber.

C. H. Newlin (Southern): Glued laminated structural lumber can be used to economic advantage in railway bridges and trestles. To do so, of course, it is necessary to use some special advantages of this new material.

In ordinary trestle construction, with usual length spans, the only place where the size advantage can be used is in the posts of multiple-story frame bents. These bents require a very large amount of labor to construct and maintain. Modern bridge gangs use derricks to handle materials, and it can be shown that the cost to handle, frame and erect the heaviest piece that the derrick can handle is only slightly more than the cost to handle the smallest piece. For this reason, substitution of continuous posts in multiple-story frame bents will greatly reduce the labor costs, although at present lumber prices the total cost will not be very much affected.

Another place where glued laminated lumber can be used in ordinary trestle construction is for caps and sills. Oak is an excellent material for this purpose, but it is not obtainable in quantity in the proper size. Also, these large sizes check very badly, resulting in poor service life. Glued laminated members with oak top and bottom and pine or fir centers have all the advantages of solid oak, plus considerable freedom from checking. When compared to southern pine or Douglas fir caps, they can be justified by the reduction in the number of posts or piles needed, except for low bents.

The use of glued laminated lumber for stringers cannot be justified if present span lengths are adhered to. Where bents are high, a saving can be realized by using longer spans.

The foregoing suggestions are not of great economic value at present prices, but they don't take very much advantage of the size possibilities for this material. Timber girders to carry railway loads on spans exceeding 100 ft are well within the size limitations. I haven't any figures on the economics of such spans, but we have for 45-ft span with Cooper E 72 loading.

In timber, one girder per rail, 22 in wide by 60 in deep, of dense southern pine or Douglas fir, will carry the load. In steel we need 36-in, 250-lb, wide-flange beams, 2-ply per rail. I believe we can obtain this timber span for about 60 percent of the cost of the steel span, in spite of the very high cost of glued laminated lumber.

These long spans and beam sizes greater than practical for solid sawn lumber are not contemplated by our specifications for design of wood bridges and trestles, which say that they are for lumber graded under AREA specifications for structural lumber.

The necessary design data are available. The changes needed are not the result of glueing and laminating, but are solely because practical beam sizes and spans have been greatly increased. The economic possibilities challenge us to act.

Vice President Hedley: Thank you, Mr. Newlin.

Is there any further discussion, or are there further questions?

R. A. Anderson (Milwaukee Road): What do you have in the way of service records on glued laminated stringers and caps in existing railroad trestles?

Mr. Schneider: Your committee reported on glued laminated bridges in service a few years ago. Since that time Mr. Ruble of the Association of American Railroads has been looking at these structures, and I understand he completed an inspection of these bridges only a few weeks ago.

Mr. Chairman, I would like to call on Mr. Ruble to report on his latest findings.

E. J. Ruble (AAR): As most of you gentlemen know, we have about five test installations—at least, so far as I know—of laminated stringers in railroad bridges.

The first installation was on the Texas & Pacific Railroad, near Washington, Tex. That was made in October of 1944.

The second installation was made on the Southern Railway at Alexandria, Va.

The third installation is on the Detroit, Toledo & Ironton Railroad, near Lima, Ohio.

There is another installation on the Chesapeake & Ohio Railway at Newport News, Va., and another on the Southern Pacific Railroad in California.

I have looked at the first three installations this year. The installation on the Texas & Pacific consists of eleven 7 by 16-in stringers, 14 ft long. They were placed in the end panel of a long bridge. It has a ballasted deck and is on the main line of the railroad. These stringers are showing just slight checking, principally on the south side where the sun is beating on them all the time. The ends of three stringers show some checking, while the remaining stringers are in excellent condition. There is no sign whatsoever of delamination, and where checking has occurred it is between the glue lines.

These stringers were fabricated of southern yellow pine, using a phenol formaldehyde resin glue, and I would say they were in excellent condition.

Adjacent stringers of full size members are showing excessive checking. Some of the checks run the full length of the stringers.

They recently took some core samples from one or two of the stringers, and it is interesting to note that the preservative has passed through the glue lines. I think the samples were about 3 in long, and the preservative is at least 2½ in deep.

The installation on the Southern at Alexandria consists of stringers, caps and posts. These are also treated, and I understand they were treated after glueing. We could find no sign of delamination in any of these stringers. However, some of the other stringers and other members are showing excessive checking.

On the Detroit, Toledo & Ironton they have caps and posts and sills. The caps were laminated by using oak plies on the top and bottom. Here, also, the laminated timbers are in very good condition. There is some checking in the oak part of the caps. However, it is not excessive. Adjacent sills, caps and posts show excessive checking.

All in all, I would say that the laminated stringers and timbers are proving very satisfactory.

We have a few small tests under way at our laboratory on laminated stringers. Our weatherometer was not in use, so we secured some laminated timbers from one of the fabricating plants. They consist of 2 by 6's, 18 in long. We have 2 of these in the weatherometer, and 2 of the full section timbers, 2 by 6 and 18 in long. They have been in the weatherometer for about 130 hr, and have been subjected to 18 cycles of freezing and thawing. We take them down to about 15 deg below zero. The laminated stringers are still in perfect condition. However, the full sections are beginning to show signs of checking.

Vice President Hedley: Thank you, Mr. Ruble.

We have a motion that has been seconded, on the adoption of the revised specifications for structural glued laminated lumber. All those in favor, say "aye"; contrary, "no." The motion is carried.

Thank you, Mr. Schneider.

Assignment 6—Design of Timber-Concrete Composite Decks, Collaborating with Committee 8, was presented by Subcommittee Chairman W. A. Oliver, professor of civil engineering, University of Illinois.

Mr. Oliver: Subcommittee 6 of Committee 7 reports progress, and as an indication of that progress, has published as information in the Bulletin a paper by T. K. May of the West Coast Lumbermen's Association. This paper, which also appears in this volume of the Proceedings, page 642, is a description and survey of the development of this composite steel, concrete and wood (perhaps I should have said "wood" first) construction that has been taking place during the past 25 years. The paper also contains a resumé of the research and laboratory studies which have been made relative to the economy of this particular form of construction for engineering structures and purposes.

If there are any comments or questions from the floor, we will receive them now. Otherwise, this is our report, Mr. Chairman.

Vice President Hedley: Thank you, Mr. Oliver.

Chairman Howe: Mr. Hedley, this concludes the report of Committee 7.

Vice President Hedley: Thank you, Mr. Howe. Your committee has again presented a number of interesting and valuable reports. We are looking to you for information and recommendations with respect to matters pertaining to the construction, maintenance, preservation and protection of wood bridges and trestles in the most effective and economical manner, and we know that your committee will carry on with diligence in the years ahead.

The committee is excused with the thanks of the Association.

(President Miller resumed the chair.)

President Miller: The next committee to report is Committee 28—Clearances, of which Mr. A. M. Weston, senior assistant engineer, Baltimore & Ohio Railroad, is chairman.

Mr. Weston, we would be glad to have you and your committee come to the platform.

Discussion on Clearances

(For report, see pp. 557–564.)

(President G. W. Miller presiding.)

Chairman A. M. Weston (Baltimore & Ohio): The AAR has recognized a definite need for closer collaboration between the committees of its different divisions and sections, and between certain other groups, with respect to questions which have arisen relative to clearances.

Thus a Joint AAR Committee on Clearances was authorized, and I am happy to report that two of our most active members accepted the nomination to serve on this committee. Mr. E. S. Birkenwald, engineer of bridges, Southern Railway, and Mr. S. M. Dahl, assistant division engineer, Chicago, Milwaukee, St. Paul and Pacific Railroad, are our representatives. Mr. Birkenwald is chairman of the committee.

Committee 28 is reporting on three of its assigned subjects. The report may be found in Bulletin 519, pages 557 to 564, incl.

A progress report on Assignment 2—Clearances as Affected by Girders Projecting Above Top of Track Rails, Signal and Train Control Equipment, will be presented by

Mr. E. S. Birkenwald, engineer of bridges of the Southern Railway System, in the absence of our newly appointed Subcommittee Chairman J. E. Good of the Reading Company.

Assignment 2—Clearances as Affected by Girders Projecting Above Top of Track Rails, Structures, Third Rail, Signal and Train Control Equipment, Collaborating with Signal and Electrical Sections, and with Mechanical and Operating Transportation Divisions, AAR, was presented by E. S. Birkenwald (Southern) in the absence of Subcommittee Chairman C. O. Bird (New York Central).

Mr. Birkenwald: This report on Assignment 2 is a brief progress statement, presented as information.

As the lower portion of our clearance diagrams for passenger and freight equipment overlaps diagrams for permanent structures or appurtenances on or adjacent to tracks, two diagrams are being developed; one for equipment, establishing a minimum distance above top of rail; and another for permanent track fixtures, establishing a maximum distance above top of rail.

A third diagram is being developed for third-rail territory based upon the above-mentioned diagrams.

President Miller: Thank you, Mr. Birkenwald.

Chairman Weston: A report as information only on Assignment 4—Compilation of the Railroad Clearance Requirements of the Various States, will be presented by Subcommittee Chairman E. R. Word, special engineer, Illinois Central Railroad.

Assignment 4—Compilation of the Railroad Clearance Requirements of the Various States, was presented by Subcommittee Chairman E. R. Word (Illinois Central).

Mr. Word: Your committee submits as information a tabulation of the clearance requirements of the various states, brought up to date as of November 17, 1954.

President Miller: Thank you, Mr. Word.

Chairman Weston: A progress report on Assignment 5—Clearance Allowances to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear and Spring Deflection, will be presented by Subcommittee Chairman S. M. Dahl, assistant division engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad.

Assignment 5—Clearance Allowances to Provide for Vertical and Horizontal Movements of Equipment Due to Lateral Play, Wear and Spring Deflection, Collaborating with the Mechanical Division, AAR, was presented by Subcommittee Chairman S. M. Dahl (Milwaukee Road).

Mr. Dahl: The work to date on this assignment has been concerned primarily with the action of passenger cars on curves. Previous reports have described the nature of the problem and the various field tests made in behalf of this committee. The report this year describes a method of determining the amount of lateral movement of a passenger car with reference to the center line of car truck at any speed on any given curve with known characteristics.

One of the more difficult aspects of this assignment is the determination of the effect of track and equipment irregularities. This matter has been given considerable attention, and a method of determining an allowance for these effects is presently being worked out. A report on this subject will be made next year.

Work on this assignment will be continued. Included in plans for 1955 is a test on freight equipment to be carried out by the AAR research staff on the Lackawanna Railroad. These tests will be similar to the tests already carried out on passenger cars, with special attention to be given to the effect of varying heights of center of gravity.

Your committee is especially grateful to Mr. G. M. Magee, director of engineering research, AAR, for his assistance in arranging the field tests, and to Mr. Randon Ferguson, electrical engineer, AAR, who had direct charge of the tests and subsequent analysis of the results. Without this help very little progress could have been reported.

President Miller: Thank you, Mr. Dahl. Your report will be received as information.

Chairman Weston: Our committee has received the following two new assignments for study and report:

First, study of track centers in relation to current clearance problems, such as permissible size of cars and locomotives in interchange service, collaborating with Committee 5 and the Joint Committee on Clearances, AAR.

Second, methods of measuring high and wide shipments.

Mr. President, this concludes the report of Committee 28.

President Miller: Thank you, Mr. Weston. The work that is being done by your committee is most important in the handling of high and wide loads, and in moving at fast speeds in new, modern types of equipment with special types of springs. We appreciate the work that you are doing in the interests of safety of train operation and railroad personnel.

Your committee is now excused with the thanks of the Association.

We will now hear the report of Committee 30—Impact and Bridge Stresses. The chairman of this committee is Mr. E. S. Birkenwald, engineer of bridges, Southern Railway System, and a director of this Association. I shall be glad if Mr. Birkenwald and members of his committee will come to the platform and present their report at this time.

I regret that we could not call for discussion on the previous report, but we are running a little behind schedule, and I want to be sure to hit the 12 o'clock time limit for the completion of our session this morning.

Discussion on Impact and Bridge Stresses

(For report, see pp. 449-452.)

(President G. W. Miller presiding.)

Chairman E. S. Birkenwald (Southern): Of the 10 committee assignments, 7 are reported on in Bulletin 519, and will be presented as information.

Advance reports of the committee were published in Bulletin 516 and cover (1) Investigation of Static and Dynamic Effects in a Bridge Consisting of Beam Spans Supported on Concrete-Filled Pipe Pile Piers, and (2) Description and Analysis of Tests Made on Transverse Floor Beams and Longitudinal Beams Under Diesel and Steam Locomotives.

Mr. M. J. Plumb, assistant engineer, New York Central System, and the chairman of the Subcommittee on Steel Structures, will give the report on Assignments 2, 3, 6, 8, 9 and 10.

Assignments 2, 3, 6, 8, 9 and 10 were presented by the chairman of the Subcommittee on Steel Structures, M. J. Plumb (New York Central).

Mr. Plumb: The subcommittee on Steel Structures of Committee 30 reports progress on six assignments.

Braking and Traction Forces in Bridge Structures, Assignment 6, and Distribution of Live Load in Bridge Floors, Assignment 9, were covered in two advance reports published in the June–July Bulletin last year (see these Proceedings, pages 1 and 45, respectively). The first one presented the results of tests on a Nickel Plate bridge at Fillmore, Ill. You will hear more about that structure in a few moments.

The second report analyzed the distribution of live loads to the floor systems of nine different bridges, some of which had transverse floorbeams and some longitudinal beams. This report verified the safety of present design methods for these floors and pointed the way to possible economies.

Your committee has reviewed and approved for publication this year a report of tests on eight steel girder spans on the Milwaukee Road. Previous reports on 13 girder spans, and a report planned for next year on 15 additional spans, will complete our program of testing girder spans. This report presents information on Assignment 2, Girder Spans; Assignment 3, Dynamic Shear; and Assignment 10, Lateral Bracings.

We have undertaken such an extensive series of tests on girder spans because, first, they represent such a large proportion of our bridge spans, and second, there are so many variables which affect the test results. Besides the normal variables of speed and weight of train and length of span, we have found that the stresses are also affected by type of floor system, by the interaction of floor and girders, the condition of the track, and the type of supports. The field work on all of these tests is done, and the oscillograms have been read for all but one span. We expect to be working next year on a summary report on all of these girder spans.

Tests were made last year on two movable bridges, at the request and expense of the railroads involved, to determine their load carrying capacity. This is included under Assignment 8 on Steel Truss Spans.

These are progress reports, presented as information.

President Miller: Thank you, Mr. Plumb. Your reports will be received as information.

Chairman Birkenwald: Report on Assignment 5—Concrete Structures, Collaborating with Committee 8, will be presented by Subcommittee Chairman J. H. Shieber, assistant engineer structures, Missouri Pacific Lines.

Assignment 5—Concrete Structures, Collaborating with Committee 8, was presented by Subcommittee Chairman J. H. Shieber (Missouri Pacific).

Mr. Shieber: As the Association knows, a full-size, prestressed, pretensioned, reinforced concrete bridge slab designed for Cooper E 72 loading was tested during 1953 at Denver, Colo. Because of its successful behavior, two additional slabs manufactured at the same time as the one tested were installed in a Burlington Railroad bridge during March 1954, where they will be tested by the AAR research staff within the next few months. A final report will be made on this service test when the data can be assembled and analyzed.

It appears that prestressed, pretensioned slabs may afford the railroads a useful and economical structural member. However, until it can be determined if the bond of concrete to the wire strands will hold up under repetitive loading, this committee—together with Committee 8—feels that caution should be used in the acceptance of this type of reinforced concrete slab.

This committee will be glad to answer any questions which may be asked from the floor.

President Miller: Thank you, Mr. Shieber.

Chairman Birkenwald: It is now my great pleasure to present to you the originator of the design of the bridge at Fillmore, Ill.—my friend and colleague, Mr. R. T. Blewitt, bridge engineer, New York, Chicago & St. Louis Railroad, who will talk to you on some of the considerations which led to the design, and on the results obtained by the committee's investigation.

Fillmore Tests of Static and Dynamic Effects in a Bridge Consisting of Beam Spans Supported on Concrete-Filled Pipe Pile Piers

By R. T. Blewitt

Bridge Engineer, New York, Chicago & St. Louis Railroad

General Introduction

I have been asked by Mr. Birkenwald to give a short talk on a steel beam, pipe pile trestle with which we replaced a treated timber trestle bridge. Because of its simple design and economy, the research division of the Armco Steel Corporation became interested in the bridge and developed sufficient interesting data to prompt a more extensive investigation of the entire structure. Committee 30—Impact and Bridge Stresses, also became interested and requested the research staff of the Association of American Railroads to conduct complete tests of the bridge. The results have been published in AREA Bulletin 516, June–July 1954, and may be found in this volume of the Proceedings beginning on page 1.

The bridge in question is the Caldwell Creek crossing at Fillmore, Ill., on the Clover Leaf Division of the Nickel Plate Road, between Frankfort, Ind., and East St. Louis, Ill. Traffic over it includes Nickel Plate locomotives which have a Cooper rating of about E 63. The original bridge was a timber pile trestle 154 ft long, with 12 pile bents containing 5 piles each. The bent spacing was 14 ft center to center. The maximum height at the center of the trestle was 28 ft 6 in, ground line to top of rail.

This bridge is one of several bridges programmed to replace treated timber trestles which had been constructed in 1933 on a rehabilitation program, and which required heavy maintenance because of the high-speed train operation. At some locations the waterway areas permitted the installation of pipes. At other locations the waterway areas were great enough to require other types of structures.

Several types of structures were investigated, giving consideration to functional suitability and to economy in cost and maintenance. Time won't permit me to itemize the various types of structures we considered, but it was determined that the bridge under discussion was the most economical type, although the treated timber trestle was a close second.

For making these comparisons the annual cost used was based on information in Part 5—Economics, of Chapter 7 of the AREA Manual. The sinking fund method was used for figuring the annual cost. The initial cost was assumed to be $35,000; the service life, 50 years, and the annual interest rate, 4½ percent. For sinking fund 3½ percent was assumed for this type of structure.

Details of Design

The bridge is a single-track structure on tangent track with level grade, and consists of five 28-ft open-deck beam spans supported on 4 pile bent piers and 2 pile pier abutments. Each span has one 33 WF 240-lb beam per rail resting on concrete caps. It was designed in accordance with the 1950 AREA specifications, using Cooper E 72 loading. The live-load impact allowance for the beam spans was 74 percent. The design load for piles was 71,000 lb per pile, which is for E 72 live load plus 25 percent impact.

The pile bent piers consist of 6 concrete-filled spiral-welded Armco pipe piles, which are 12¾-in outside diameter with a ¼-in wall thickness. The 4 corner piles in each pier were driven with a batter of 1 to 12 transverse to the center line of track. The 6 piles (3 piles to each bent—bent spacing 3 ft) in each pier are capped with a poured-in-place reinforced concrete cap 5 ft 6 in wide, 4 ft deep and 12 ft 6 in long. Each pile extends into the cap a distance of 1 ft. The pile spacing at the cap, for uniform loading on each pile, is 4 ft 3 in; the pier bents were spaced between the old bents.

Although the use of bracing for the pile bents was not originally anticipated, it was decided to brace both longitudinally and laterally the two center piers, the piles of which had an unsupported length of more than 20 ft.

Design Factors

The design factors contributing to the economic advantage of this bridge include the following:

1. The use of rolled section beams instead of fabricated girders reduces fabrication costs to the minimum.
2. The fabricated spans are light enough to handle with a locomotive crane.
3. Locating the new bents between the existing bents eliminates additional falsework.
4. The concrete caps finish below the bottom of the wood stringers, so the stringers may remain in place while the substructure of the new bridge is placed.
5. The work is done with available on-track equipment.
6. The use of pipe piles provided light weight for maximum strength, cut-offs were economically salvaged, and the piles were easily inspected after being placed.
7. The design of the concrete cap facilitates accurate placement of the steel spans under controlled conditions.
8. Slow orders are held to the minimum.

As the use of pipe piles for this bridge was in the nature of an experiment, I believe it would be well to discuss these piles, both with regard to our experiences with them and the results obtained from investigation in the field.

The piles were driven with a No. 1 Vulcan single-acting steam hammer which has a rated energy of 15,000 ft-lb, and were driven to a resistance of 60 blows per foot, calculated to carry 50 tons. The piles were driven in sections; the first section had a closed end consisting of a ¾-in plate welded to the bottom of the pile. The driving end of the pile was square; the remaining sections were square at one end and had a 30-deg bevel at the other end. The bevel end was provided to permit splicing of the pile sections by welding, and to facilitate splicing of the pile, a pipe sleeve was used. When the piles were driven, a pipe pile helmet was used.

We have replaced several timber trestles with this type of bridge, and in all cases except one, which had a shale bottom, we have driven the piling 4 to 8 ft deeper than the timber piles had been driven. Since the steel pile is approximately no heavier than an average wood pile, we had no difficulty placing them into the leads. No sweeping of piles was experienced as each one was examined by a light before concreting; we believe there is less chance for a pile to sweep when using flat steel plate ends instead of steel points or shoes. There is very little pile waste because of the easy manner in which the piles can be spliced.

Field Investigation

The field tests in various parts of the bridge were made with a special test train operating over a complete range of speeds from 5 mph to a maximum of 58 mph. The tests of the piles included measurement of stresses on the concrete filled piles with and without timber bracing. With the timber bracing in place the piles were tested near the ground line. With the timber bracing removed the piles were tested at the ground line, at mid-height and near the concrete cap. With respect to the piles, the following observations were made:

1. The maximum recorded pile loads for all piles was about 50 kips and the bracing had no effect on the magnitude of the pile loads, as would be expected.
2. The greatest impact recorded amounted to 26.5 percent of the recorded static load and occurred on one of the piles with the timber bracing removed.
3. The distribution of the live load to the individual piles in each pier varied from 13 to 20 percent, compared with an average of 16.7 percent, which is a perfect distribution for each pile. The battered piles carried a full share of the load.
4. The tests indicated that the piles were subjected to lateral and longitudinal bending. However, the bending was considerably below that calculated by using AREA requirements. For instance, the equivalent lateral force necessary to produce the lateral bending stresses recorded in the piles is about 4.5 kips, compared with AREA design force of 20 kips. The greatest longitudinal force taken by one pier was 2.25 kips, compared with AREA design force of 39 kips, or 15 percent of the pier reaction. It was found there was less bending and vibration on the piles with bracing.

Result of Tests

The tests have shown this type of structure to be well balanced structurally. The allowance of 25 percent of the live load for impact existed in the piles and should be provided for in the design.

It is believed that considerable savings could be made on the piling by:

(a) Increasing the span length
(b) Decreasing the diameter of pile shell, or
(c) Decreasing the number of piles per pier.

I believe it can be assumed that no bracing for the bents is necessary for a pile having an unsupported length which is 20 ft or less from the point of fixity and the underside of cap, assuming the point of fixity as 5 ft below existing ground. Where this length is exceeded, cross sway bracing should be installed in tiers, each tier not to exceed a height of 20 ft.

It should not be assumed from this discussion that steel pipe piles have preference over other piles for this type of structure. Rather, it is an attempt to relate the physical characteristics of the pipe piles determined by the field tests and investigations, the results of which could well apply to other kinds of piles for this type of structure.

In conclusion I would like to express my thanks to the members of the research staff of the Association of American Railroads, and to the Armco Steel Corporation for their efforts in making the field investigations and for the excellent reports prepared as a result of these tests. The information developed is available and is just one more contribution to enable us to design structures to meet the necessity for economy, as well as good design.

President Miller: Thank you, Mr. Blewitt. You have presented a most interesting paper.

Chairman Birkenwald: Mr. President, this concludes the report of Committee 30.

President Miller: Thank you, Mr. Birkenwald. Your committee has many interesting and important investigations under way, and we appreciate not alone the work which is being done under its direction, but the highlight review of this work which you have presented to us this morning.

Your committee is now excused with the thanks of the Association.

The next committee to report is Committee 8—Masonry. The chairman of this committee is Mr. W. R. Wilson, assistant engineer, Santa Fe, Chicago. Will Mr. Wilson and members of his committee please come to the platform?

Discussion on Masonry

(For report, see pp. 483–487.)

(President G. W. Miller presiding.)

Chairman W. R. Wilson (Santa Fe): The report of Committee 8 will be found in Bulletin 519, pages 483 to 487, incl.

It is my sad duty to report that Mr. James Fulton Leonard, past chairman of Committee 8, died on March 18, 1954. His memoir is presented as part of our report.

Your committee reports on three assignments this year, and reports progress on the remaining five assignments.

The report on Assignment 2—Principles of Design of Masonry Structures, will be presented by the subcommittee chairman, Mr. R. L. Mays, assistant to chief engineer of the Nickel Plate Railroad.

Assignment 2—Principles of Design of Masonry Structures, Including Design of Masonry Culverts, Collaborating with Committees 1, 5, 6, 7, 13, 15, 28, 29 and 30, was presented by Subcommittee Chairman R. L. Mays (Nickel Plate).

Mr. Mays: Many railroad engineers have felt that the present ASTM specifications are not adequate in design and strength requirements for construction of reinforced concrete culvert pipe for railroad use, and that specifications should be prepared for stronger pipe. Committee 8 has undertaken this job, and the new specifications which it has prepared are similar to those of the ASTM, but with increased test loads and reinforcement requirements.

Designs were prepared for sections of pipes ranging in sizes from 15 to 84-in diameters for two classes of pipes designated in the specifications as Standard Strength Reinforced Concrete Culvert Pipe and Extra-Strength Reinforced Concrete Culvert Pipe. After the designs were completed, it was felt that the sections for the various sizes and classes of pipes should be subjected to a full-size strength test to verify the strength requirements of the specifications for the 0.01-in crack.

Accordingly, Committee 8 requested Committee 30—Impact and Bridge Stresses, to secure laboratory data from full-size strength tests of pipes made in accordance with the proposed specifications. To secure these data, arrangements were made by the AAR for the manufacture of 36 pieces of pipes, varying in size from 24 to 84 in diameters, in accordance with the proposed specifications. The pipes were manufactured by the Massey Concrete Products Company under regular plant conditions in accordance with the proposed specifications, and after being properly cured were shipped to the testing laboratory of the Chesapeake & Ohio Railway at Huntington, W. Va., where full-size tests were carried out under the direction of the AAR research staff. The tests were carried on under the general direction of G. M. Magee, director of engineering research, with the field direction under E. J. Ruble, research engineer of structures of the AAR staff.

It was found that the tests verified very closely the design calculations and that the pipes met the test requirements for the 0.01-in crack. A detailed report of these tests was printed in Vol. 55 of the Proceedings, 1954, pages 245 to 342 incl.

Last year your committee submitted, as information, Specifications for Reinforced Concrete Pipe, which appear in the Proceedings, Vol. 55, 1954, pages 476 to 485, incl. These specifications are now offered for adoption and inclusion in the Manual at the end of Part 10 of Chapter 8, with the following changes in Sec. C, Art. 5:

Delete the first sentence and replace with the following:

"If the splices are not welded, the reinforcement shall be lapped not less than 20 diameters for deformed bars manufactured in accordance with ASTM Designation A-305, and 40 diameters for cold-drawn wire and plain bars."

Delete the figure "48" in the sixth line of the paragraph and replace with the figure "36".

Your committee would welcome any questions or discussion pertaining to these specifications.

Mr. President: I move that the Specifications for Reinforced Concrete Culvert Pipe as submitted last year and printed in Vol. 55 of the Proceedings for 1954, pages 476 to 485, incl., with revisions as stated, be adopted and included in the Manual.

T. J. Schoener (Missouri Pacific): I would like to know why the specifications cover only pipe up to 84 in. in diameter.

Mr. Mays: Your committee felt that these pipes would be the sizes most commonly used. The committee also felt that any pipe larger than 84 in. in diameter might merit special consideration. It might be desirable on the part of some railroads to increase the wall thickness greater than that normally used, and there are possibly other considerations.

The specifications provide for an alternate design, and your committee definitely feels that any pipe larger than 84 in should receive special consideration insofar as design is concerned.

President Miller: You have heard the motion. Is there a second?

(The motion was regularly seconded.)

F. E. Schneider (Santa Fe): Has the committee made any adjustment in the specification for installation of the pipe, taking into account the difference between the three-edge bearing method used in the test data and that used in actual installations?

Mr. Mays: Your committee realizes that the three-edge or three-point bearing support is much more severe than the actual conditions that will result under traffic or under loading. The three-point bearing, three-edge bearing test is a test only for the quality of material that is used in the pipe. The pipe should still be placed in accordance with the specifications now printed in Chapter 8 of the Manual, under Part 10.

President Miller: Are there any further questions?

(The motion was put to a vote, and carried.)

Chairman Wilson: The report on Assignment 4—Earth Pressure as Related to Masonry Structures, will be presented by Subcommittee Chairman Dr. R. B. Peck, research professor of soil mechanics, University of Illinois.

Assignment 4—Earth Pressure as Related to Masonry Structures, was presented by Subcommittee Chairman R. B. Peck (University of Illinois).

Mr. Peck: Committee 1—Roadway and Ballast, with the collaboration of Committee 8, has prepared Specifications for Test Borings, which were published in the

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Proceedings, Vol. 55, 1954, pages 622–628, and will be submitted for adoption this year. To avoid duplication in the Manual, your committee recommends that the Specifications for Test Borings now included in Part 3, Chapter 8 of the Manual, pages 8-3-1 to 8-3-7, incl., be deleted when the Association adopts the Specifications for Test Borings prepared by Committee 1.

Mr. President, I move the adoption of this recommendation.

(The motion was regularly seconded, was put to a vote, and carried.)

President Miller: Thank you, Mr. Peck.

Chairman Wilson: The report on Assignment 8—Specifications for the Construction and Maintenance of Masonry Structures, will be presented by Subcommittee Chairman R. E. Paulson, assistant engineer on the Chicago, Milwaukee, St. Paul & Pacific Railroad.

Assignment 8—Specifications for the Construction and Maintenance of Masonry Structures, was presented by Subcommittee Chairman R. E. Paulson (Milwaukee Road).

(Mr. Paulson read the report of the committee, pages 486–487 of Bulletin 519, and then moved that the proposed changes be adopted.)

(The motion was regularly seconded, was put to a vote, and carried.)

President Miller: Thank you, Mr. Paulson.

Chairman Wilson: Mr. President, this concludes my three-year term as chairman of Committee 8—Masonry. It has been a very pleasant three years, made so by the wonderful group of men who constitute Committee 8. I wish to thank them for the cooperation they have given me. Any job I asked them to do was done cheerfully and enthusiastically.

At this time I wish to introduce your new chairman and vice chairman.

Your new chairman is Mr. M. S. Norris, regional engineer, Baltimore & Ohio Railroad, and I know that your committee is in good hands with Mr. Norris.

Your new vice chairman is Mr. E. A. McLeod, district engineer of structures, New York Central System, who will ably assist Mr. Norris.

President Miller: Mr. Wilson, I want to congratulate you on the completion of your three-year term of office as chairman of Committee 8. Under your direction the committee has continued to accomplish much, and I want you to know that your interest and efforts are greatly appreciated.

We are glad to welcome Mr. Norris as your successor, and are sure that under his direction the work of the committee will go forward aggressively.

I would like to present to Mr. Norris a chairman's gavel as a symbol of his authority. The headband on the gavel reads, "M. S. Norris, Chairman, Committee 8, 1955–1957."

M. S. Norris (Baltimore & Ohio): Thank you very much.

President Miller: Thank you again, Mr. Wilson.

Your committee is now excused with the thanks of the Association.

The final report this morning will be from Committee 15—Iron and Steel Structures. The chairman of this committee is Mr. J. F. Marsh, engineer of bridges, Chicago, Rock Island & Pacific Railroad, Chicago. I would ask that Mr. Marsh and other members of his committee please come to the platform and present their report.

Discussion on Iron and Steel Structures

(For report, see pp. 589–634.)

(President G. W. Miller presiding.)

Chairman J. F. Marsh (Rock Island): Mr. President, members of the Association and guests: The report of Committee 15 is printed in Bulletin 520, pages 589 to 634, incl. (same pages in these Proceedings). Your committee is reporting on 4 of its 11 assignments.

Mr. E. S. Birkenwald, engineer of bridges, Southern Railway, will report on Assignment 1—Revision of Manual.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman E. S. Birkenwald (Southern).

Mr. Birkenwald: On page 15–1–33 of the Manual, Art. 2, Sec. B of the Specifications for Steel Railway Bridges, a revision is needed so as to conform to ASTM specifications. Essentially, the revision is one of simplification. I, therefore, move that the proposed revision indicated on page 590, Bulletin 520 (same page these Proceedings), be adopted and published by the Association.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. Birkenwald: A digest of tests on the finishing of structural plate edges is presented as information. The research was financed jointly by the AAR and the University of Illinois, with contributions of material for testing by some of the steel manufacturers. Four kinds of steel were tested, a rimmed steel and a semi-killed steel meeting ASTM A–7 specifications; a structural silicon steel meeting ASTM A–94 specifications; and a low-alloy, high-tensile steel meeting ASTM A–242 specifications.

Small specimens were prepared in which the edges were either machined, sheared, flame-cut manually, flame-cut by machine, or flame-cut followed by flame softening or post heating. The specimens were tested by applying static tensile loads to determine the effect of the edge condition on the strength and ductility of the specimen.

Of particular interest to the committee and to the Association—as they affect the writing of specifications for steel railway bridges—are the following facts which were developed from the steels tested:

1. Shearing impairs the ductility, and may reduce the strength of certain steels.

2. To avoid impairment of strength and ductility, the automatic flame-cutting technique must be used, and for silicon steel this technique must be followed by post heating or the flame-softening of the edge.

3. Brittle fracture near the ultimate strength of the materials tested can be assured with the use of better fabricating techniques.

4. Machining does not affect either strength or ductility.

President Miller: Thank you, Mr. Birkenwald.

Chairman Marsh: Mr. Sandberg, assistant bridge engineer, system, Santa Fe, will report on Assignment 4—Stress Distribution in Bridge Frames.

Assignment 4—Stress Distribution in Bridge Frames, (a) Floorbeam Hangers, (b) Counterweight Trusses of Bascule Bridges, (c) Model Railway Truss Bridge, was presented by Subcommittee Chairman C. H. Sandberg (Santa Fe).

Mr. Sandberg: This subcommittee has been busy for the last several years investigating the causes and possible remedies for failures in floorbeam hangers of railroad truss bridges.

This project is now nearing the end, and it only remains to complete the writing up of three field tests.

This year, in Bulletin 517 (see page 217 these Proceedings), there was published some test result on two large riveted and bolted joints. This research work has been handled by Purdue University, assisted by Mr. Magee and his staff. We owe a great deal of the success of this project to Professor L. T. Wyly and his staff at Purdue University.

This report is offered as information.

President Miller: Thank you, Mr. Sandberg. Your report will be so received.

Chairman Marsh: Mr. R. C. Baker, engineer of structures, Chicago & Eastern Illinois Railroad, will report on Assignment 6—Preparation and Painting of Steel Surfaces.

Assignment 6—Preparation and Painting of Steel Surfaces, was presented by Subcommittee Chairman R. C. Baker (Chicago & Eastern Illinois).

Mr. Baker: From the progress report of this subcommittee it is noted that to date the work of the committee has been confined to the following:

First, cooperation with the Steel Structures Painting Council. Vol. 2 of the Painting Manual was given to the printers early this year, and we had planned that this volume would be distributed to the Member Roads by this time, but the printing was not completed in time. However, one copy was mailed to the AAR Research Center so that it would be on display here in the lobby outside this meeting room for your inspection. One copy of this volume will be mailed to each of the chief engineers of Member Roads, and one copy to each member of Committees 6 and 15 of the AREA. Additional copies will be available at $6 per copy.

Copies of Vol. 1 of the Manual are still available, and combined with Vol. 2 provide the only full textbook on the painting of steel surfaces that we know of on the market today. We feel that these volumes should be in the possession of all railroad men interested in the painting of steel structures.

Second, field tests of various painting systems. We have mentioned painting systems already under way, such as the AAR paint tests here in Chicago, the Santa Fe Railroad service paint test, and the Missouri Pacific Railroad brine drippings test.

Committee 15 has requested that your subcommittee conduct and report on two new paint tests. The first test is to determine the relative performance of a number of paint systems on a new bridge, half of which would be shop cleaned and primed, the other half allowed to weather and then cleaned in the field before priming and painting. The other test involves the suitability and performance of various synthetic resin paints on brine-contaminated surfaces of a bridge in actual service, which can be cleaned by hand, but without steam cleaning.

These paint tests are to be conducted jointly by the AAR, the Painting Council, and this committee. To carry out this test program, we need the cooperation of a railroad for each of the tests, the railroad to furnish the bridge suitable for the test, the necessary paint and supplies, and the labor to clean and apply the various paints. Your interest and cooperation in this phase of this assignment will be greatly appreciated, and if there is any road that is interested, it should contact either this committee or the AAR, or Dr. Joseph Bigos of the Steel Structures Painting Council.

President Miller: Thank you, Mr. Baker. The work being done by your subcommittee is certainly of great value to the railway industry.

Is there any discussion?

Proceed, Mr. Chairman.

Chairman Marsh: Mr. Rankin, bridge engineer, Texas & Pacific Railway, will report on Assignment 9—Use of High-Strength Structural Bolts in Steel Railway Bridges.

Assignment 9—Use of High-Strength Structural Bolts in Steel Railway Bridges, was presented by Subcommittee Chairman A. G. Rankin (Texas & Pacific).

MR. RANKIN: Mr. President, this final report deals with the use of high-strength steel bolts in steel railway bridges, and is divided into three parts. Part 3 will be presented first.

The present Specifications for Assembly of Structural Joints Using High Tensile Steel Bolts in Steel Railway Bridges were only adopted in 1953; however, the technical knowledge gained from the large amount of research on this new type of fastener and the practical knowledge obtained from the installation of millions of the bolts in actual structures have made desirable extensive revision of these specifications. Some of the more important revisions have to do with the identification of the bolts by three radial lines on the head; the use of beveled washers only when the bearing faces under the hardened washers are out of parallel by more than 5 percent; the inclusion of recommended bolt tension values for calibrating impact wrenches; and a change in the inspection requirements.

Mr. President, I move that the revised specifications which are to be substituted for the present specifications be adopted by this convention for inclusion in the Manual.

(The motion was regularly seconded.)

PRESIDENT MILLER: The motion has been made and seconded. Is there any discussion?

H. E. WILSON (Santa Fe): Mr. President, under the scope of these specifications, Part 1c, it reads, "Construction shall conform to existing codes for riveted structures, except as provided herein." My question is: what is the intent or the meaning of the "existing codes"?

MR. RANKIN: Mr. Wilson, the intent is that the erection shall conform to the AREA Specifications for Erection of Steel Railway Bridges.

MR. WILSON: I move that the original motion be amended to revise Sec. A, Art. 1c, to read, "Erection shall conform to the AREA Specifications for Erection of Steel Railway Bridges."

(The motion was regularly seconded.)

G. E. ROBINSON (New York Central): Does Mr. Wilson intend to omit the last phrase, "except as provided herein"? I believe that should be included.

MR. WILSON: I agree with that, Mr. Robinson.

PRESIDENT MILLER: Has the subcommittee any comment to make on this suggested change?

MR. RANKIN: As I understand it now, "The erection shall conform to the AREA specifications for erection of steel railway bridges, except as provided herein." Is that correct?

MR. WILSON: That's right.

PRESIDENT MILLER: You have heard the amendment to the original motion. It has been seconded. All in favor of the amendment, say "aye"; contrary, "no." Carried.

The original motion, as amended, will now be presented for approval. All in favor, please say "aye"; contrary? Carried.

MR. RANKIN: Parts 1 and 2 of this report deal with recent inspections of our experimental installations of these bolts in steel railway bridges and with a method of tightening high-strength bolts in which the bolt tension is correlated with turns of the nut from a "finger tight" position.

In 1948 the research staff of the Association of American Railroads installed high-strength structural bolts in 12 different railroad bridges to determine if these bolts would stay tight in particular locations where trouble had been encountered in keeping rivets tight. Additional installations were made in 1950 in three bridges in a northern climate to determine if such bolts were adversely affected by severe winter temperatures. These bolts have been inspected periodically since their installation, and details covering the installation and inspections, such as the railroad, location, number and size of bolts, the date of installation, and the various inspection dates, are shown in the report.

The bolted joints have proved superior to riveted joints as they stayed tight six or seven years in locations where rivets were working loose about every year.

There has been some loss of clamping action in some of the bolts, but we feel that the new method of tightening, as recommended in Part 2 of this report, will provide surplus clamping action so that the final clamping force will be above the minimum required.

Inspections show that bolts which were installed in bridges where temperature often falls to 40 deg below zero have proven satisfactory.

It is quite evident from our experience that it is economical to use high-strength bolts in railway bridges, especially for maintenance. In many railway bridges inspectors find fewer than 40 loose rivets, and the cost of a large steel gang and heavy equipment is often prohibitive for replacing a small number of rivets. One previous objection to the use of these bolts was that there was no practical method of making sure that the bolts were drawn up. The following report offers a new method of tightening the bolts, which assures that they will have the proper clamping force. This method consists principally of tightening the bolt first with the fingers and then giving the nut one complete revolution. The interesting part of this method is that it has been found to apply to bolts of all diameters and lengths usually found in railroad bridges. The method also applies to bolts tightened either manually or with power wrenches.

We are submitting Parts 1 and 2 as information, and will be glad to answer any questions from the floor on this subject.

J. S. Hancock (Detroit, Toledo & Ironton): You speak about one turn from a finger-tight position. It looks to me as though it would make a lot of difference how tight your plates were together. Is there some way of knowing how tight your plates are at this "finger-tight" position?

Mr. Rankin: It is true our studies have been made on laboratory tests, but we have also had some experience in field installations.

The AREA specifications for erection of steel railway bridges require that the steel should be first drawn together with fitting-up bolts and pins in 50 percent of the holes. It is generally agreed that the same rules would apply to the use of high-strength bolts for fitting-up bolts for permanent fastening. Common practice is now to use high-strength bolts for fitting-up bolts. This involves filling about 25 percent of the holes with high-strength bolts and tightening them to draw up the steel.

These bolts are marked for later identification, and the remaining holes are filled with high-strength bolts which are given one full turn from finger-tight position. If the steel has been hard to draw together, these bolts should be loosened and given more than one and one-half turns from the finger-tight position. This would allow for a little yielding in the bolt and the nut threads in the first tightening.

Does that answer your question?

President Miller: Thank you, Mr. Rankin.

H. C. Prince (American Bridge Division, U. S. Steel Corporation): Is it satisfactory to tighten high-tensile bolts into the plastic range of steel?

Mr. Rankin: Yes. The AAR tests indicate that it will require about two and one-half turns to break the bolt or strip the threads. Laboratory tests conducted by the

Research Council on Riveted and Bolted Structural Joints show that the bolts tightened into the plastic range are stronger in fatigue than those bolts tightened up to elastic proof load. This also applies to joints with bolts loaded in direct tension.

President Miller: Any further discussion? This is one of the most important developments in recent years. I am sure it will result in great economy in maintenance and construction work insofar as bridges are concerned. I am sure you all compliment this subcommittee on the report it has presented.

Chairman Marsh: Mr. President, this concludes the report of the Committee on Iron and Steel Structures.

President Miller: Mr. Marsh, working with the research staff of the Engineering Division and other groups, your committee continues to make most valuable studies and reports. We greatly appreciate the large amount of information which you have brought together and submitted this year in your current report.

Your committee is now excused, with the thanks of the Association.

Southern Railway Film on Mechanized Track Maintenance

The last item on our program this morning is a film on mechanized tie renewals and track surfacing on the Southern Railway. Some of our members saw this a few weeks ago, and I asked Mr. Brosnan, vice president-operations, of the Southern Railway System, if it could be shown here today. His reply was just what you would expect. He said, in part, "We have borrowed a lot of ideas in the past from our neighbors. If we have something new which they can now borrow from us, we're happy to accommodate them." That is the true spirit of our Association work.

So, without further comment, I will turn the meeting over to Mr. C. H. Fox, process engineer, Southern Railway, who will introduce the picture and comment on its presentation. Mr. Fox, would you come up to the rostrum?

C. H. Fox (Southern): Gentlemen, you are about to see a picture that was made February 11, 1955, which shows one of our timbering and surfacing operations. As the picture progresses, it will show some of the outstanding features of the operation.

(Showing of motion picture.)

Mr. Fox: Note the number of men required in this operation—1 foreman, 2 assistant foremen, 9 operators, 13 laborers, or a total of 25 men, plus 2 flagmen.

This schematic diagram shows working positions of men and machines of this gang.

You will notice the tie machines have two tie cars. Working in the yards, new ties are carried out on one car and the old ties are placed on the other car as removed from the track.

This is a machine for unloading cross ties. It is now moving from the machine car into the car containing cross ties.

This is a close-up, showing how the ties are pushed from the car by the revolving chain. These ties can be unloaded on either side of the car by reversing the chain. This chain is fully controlled by the operator.

Here you see the ties being unloaded perpendicular to the track. When the ties are to be unloaded, the operator is signaled by the supervisor by tapping on the side of the car. This operation only requires the machine operator and the supervisor. Since this picture was made, we have adopted the use of a radio for the supervisor to use in notifying the operator when a tie is to be removed from the car.

This car is designed to hold 400 ties, which are unloaded into the car without bands or special fastenings.

All cross ties to be removed from track are marked in advance by the track supervisor. This marking is used in unloading new ties at the right places.

This machine will travel from one tie car into the other without being switched.

The machine, having finished unloading all ties, is now moving back to the machine car, where it will be blocked in place for moving in the train. The equipment is now approaching, on its way out for the day's work.

Next we see Operation 1, which is a ballast regulator, manned by one operator. This machine is equipped with a special wing, and is used in plowing ballast from the ends of the cross ties that are to be removed. It is only necessary to remove the ballast from one end of the ties. The ballast is plowed away to allow free working room.

Operation 2 consists of an operator with a hydraulic spike puller, which removes all spikes from each tie marked. The pulled spikes are picked up by the operator and placed in a can carried on the side of the machine. As soon as the pulled spikes fill the can, a new can is put on. All rail anchors against the ties to be replaced are also removed by the operator.

Now approaches Operations 3 and 4.

Each machine is manned by one operator and two laborers. This picture shows the right side of the Tiemasters, which illustrates how the chain assembly operates in pushing old ties out and pulling new ties in. This is a complete cycle with the machine pushing out an old tie and pulling in a new tie. As the chain moves in under the rail, the old tie is pushed out on the opposite side. As the chain is pulled in, it brings the new tie into place under the rails.

This is a view showing ties being pushed from track and loaded on tie cars. This also illustrates how the ties can be pushed out over an adjacent track.

In renewing ties in yards or adjacent main tracks of the same elevation, we have a pin we place on adjacent track so the tie will slide over the rails. This can be done without any trouble.

The hoist for handling the cross ties is mechanically operated, fully controlled by the laborer.

This shows a tie plate being removed from an old tie and placed on the new tie.

The day this picture was made, February 11, the two Tiemasters installed 447 cross ties, with an on-track working time of 4 hr, 48 min.

All ties removed from track are bundled in bundles of 16 ties and banded and dumped at side of track. These bundles are picked up at a later date, and the ties are used in passing tracks, yard tracks and secondary main tracks.

Operation 6, consists of operator and Spikemaster. This machine nips the ties and drives the spikes that have been set by three laborers in Operation 5.

The three laborers in Operation 5 keep a standard track gage with them. The gage is checked all along, and corrected when necessary.

When more than four ties are installed at one place, one of the ties is spiked to gage in Operation 5.

Please note the spikes that have been set ahead of the spiker in Operation 5.

This shows the spikes being driven on the left-hand side of the machine. This machine spikes both sides.

This shows how the nipping bars take hold of the cross tie and nip it up into place.

Operation 7, consists of an operator and ballast regulator and crossing scarifier. This machine is used to pull ballast from the outside into the track ahead of the tamping operation. The ballast was unloaded ahead of the tamping from ballast cars off of the end of the ties. This illustrates how the ballast is pulled in over the top of the rails.

The operator of this machine also rips out all grade crossings with the scarifier, ahead of the tamping operation. A radio for the foreman's use in getting the lineup of trains is also installed on this ballast regulator.

This shows the operator removing drive screws from wooden guard rails by means of an impact wrench. The motor for operating this impact wrench is also installed on the ballast regulator. The wooden guard rails are being removed from track by the operator after the drive screws have been removed. This is a one-man operation.

You now see a scarifying attachment ripping out the pavement at a crossing. This scarifier removes the pavement to the top of the ties. It makes a cut of 9 ft, which gives ample room for renewing cross ties in the tamping operation. The winch which you see is controlled by the operator and is used in pulling the machine through the crossing at the desired speed. One end of the cable is fastened to the rail ahead of the crossing, through a block.

This is the crossing after it has been ripped out.

Operation 8 involves a self-propelled cart which transports jacks from the tamper to the head jack men. This cart is kept in motion while the tamping operation is in progress, so there will be no accumulation of jacks at the tamper. The speed of this cart is 3 mph. As soon as the jacks have been unloaded from the cart, it is reversed by the laborer for a return trip to the tamper.

The two head jack men alternate in unloading jacks from the jack cart. Ten-inch aluminum jacks are used, 18 to the side. This jack cart picks the jacks up and reverses itself automatically. As the jacks are removed from the track, they are set on the jack platforms by the laborers working at the machines.

In Operation 9, two pneumatic multiple tampers are worked in tandem. Each machine tamps every other tie.

This illustrates how the ballast has been pulled into the track by the ballast operator. The jacks are set opposite each other, six ties apart. This is done so the head tamper will always tamp the closest tie to the jack before it is removed from the track. We use 1½-in granite ballast.

The second tamper is manned with one operator. This machine tamps exactly as many ties as the head tamper. We have found that by using the tampers in tandem, it was not necessary to increase our force organization.

On February 11, the day this picture was made, these machines tamped 3895 track feet in 4 hr and 48 min on-track time.

The jack is never removed from the track until the tie next to the jack has been tamped off.

This shows tampers being used in tamping through a turnout; it was 80 percent tamped by machine and 20 percent by hand.

Operation 10, shows the Linemaster, operator, and assistant foreman. The assistant foreman sights the track to line.

This shows how the Linemaster is loaded on a trailer car behind the second tamper by the assistant foreman, the operator of the tamper, and the operator of the Linemaster.

The equipment is now going into the clear. This is the ballast regulator you first saw in Operation 1. This regulator works one-half of the shift.

This is finished track, except for removing the ballast from in between the rails, which will be done by a mechanically operated broom. Please note the bundles of ties alongside the track, which will be picked up at a later date by a crane.

The equipment is now in the clear at the end of the day's operation.

We thank you. (Applause)

President Miller: Thank you, Mr. Fox. I congratulate you people on the Southern for what you are doing to mechanize maintenance operations and reduce costs, and also upon the very effective oral and pictorial description of the work which you are doing.

The presentation of this film is a logical introduction to our first committee reports this afternoon. I refer to Committee 27—Maintenance of Way Work Equipment, followed by Committee 22—Economics of Railway Labor. The first report will be given in this room this afternoon at 2:30. This completes the morning session, and I would ask that you now all go immediately to the annual luncheon, which is about to be held in the Grand Ballroom.

(The meeting recessed at 12:10 p.m.)

Annual Luncheon Program

Grand Ballroom—1:40 pm

Wednesday, March 16, 1955

President Miller: Members of the Association, friends and honored guests: May I suggest that we begin our program by singing the National Anthem of the United States, followed by the National Anthem of Canada, "God Save the Queen."

(Singing of National Anthems of United States and Canada by the audience.)

President Miller: As president of the American Railway Engineering Association, I am delighted with this large attendance at our Annual Luncheon. The attendance here totals 1270, which is the first time we have exceeded 1200. Last year we had 1162. I welcome you here.

We are specially honored by the presence at our speakers' table of a number of executive officers of various railroads, in addition to the several officers and past presidents of the American Railway Engineering Association. I want to present these men to you at this time. As each guest is introduced, I would ask that he please stand and remain standing until all introductions have been completed. May I also ask that you withhold your applause until our last guest has been introduced.

Commencing at the far end of the table to my right, Mr. H. S. Loeffler, past president of the AREA, 1950–1951, assistant chief engineer, Great Northern Railway, St. Paul, Minn.; Mr. C. G. Grove, past president of the AREA, 1953–1954, chief engineer, Western Region, Pennsylvania Railroad, Chicago; Mr. C. J. Geyer, past president of the AREA, 1952–1953, retired vice president—construction and maintenance, Chesapeake & Ohio Railroad, Richmond, Va.; Mr. Armstrong Chinn, past president of the AREA, 1947–1948, president, Terminal Railroad Association of St. Louis, St. Louis, Mo.; H. C. Murphy, president, Burlington Lines, Chicago; Mr. J. P. Newell, vice president—operations, Pennsylvania Railroad; Mr. William J. Hedley, junior vice president, AREA, and assistant chief engineer, Wabash Railroad; Mr. Jess Mossgrove, president, National Railway Appliances Association.

I will pass over the gentleman to my right, and introduce him later.

Next is Mr. G. M. O'Rourke, senior vice president, AREA, and assistant engineer maintenance of way, Illinois Central Railroad; Mr. J. P. Kiley, president, Chicago, Milwaukee, St. Paul & Pacific Railroad; Mr. D. W. Brosnan, vice president operations, Southern Railway System, Washington, D. C.; Mr. H. H. Pevler, vice president, Pennsylvania Railroad, Chicago; Mr. S. F. Dingle, vice president, Canadian National Railways, Montreal; Mr. G. M. Campbell, vice president and executive representative, Baltimore & Ohio Railroad, Chicago; Mr. T. D. Bevin, president, Elgin, Joliet & Eastern

Railway, Chicago; Mr. A. R. Wilson, past president, AREA, 1936–1937, retired engineer of bridges and buildings, Pennsylvania Railroad; Mr. C. H. Mottier, past president, AREA, 1948–1949, vice president and chief engineer, Illinois Central Railroad; and Mr. W. S. Lacher, Secretary Emeritus, AREA.

Gentlemen, this is your head table. (Applause)

It now gives me the greatest of pleasure to recognize those men at the table immediately in front of me, as they are the chairmen of our standing and special committees—the men who are the backbone of our intensive committee work, and without whose diligent interest and effort we could not succeed as an Association.

As I introduce each committee chairman, may I ask that he stand and remain standing until all have been introduced? And again, I would ask that you withhold your applause.

Chairman of Committee 1—Roadway and Ballast, Mr. B. H. Crosland, assistant chief engineer, St. Louis–San Francisco Railway.

Chairman of Committee 3—Ties, P. D. Brentlinger, forester, Pennsylvania Railroad.

Chairman of Committee 4—Rail, C. J. Code, assistant chief engineer—engineer of tests, Pennsylvania Railroad.

Vice Chairman of Committee 5—Track, W. E. Cornell, engineer of track, New York, Chicago & St. Louis Railroad, who is sitting in for Chairman L. L. Adams, chief engineer, Louisville & Nashville Railroad, who was unable to be present today.

Chairman of Committee 6—Buildings, O. W. Stephens, assistant to chief engineer—maintenance, Delaware & Hudson Railroad.

Chairman of Committee 7—Wood Bridges and Trestles, W. C. Howe, engineer of bridges and buildings, Bessemer & Lake Erie Railroad.

Chairman of Committee 8—Masonry, W. R. Wilson, assistant engineer, bridge department, Santa Fe Railway.

Chairman of Committee 9—Highways, W. C. Pinschmidt, engineering assistant to vice president—construction and maintenance, Chesapeake & Ohio Railway.

Chairman of Committee 11—Records and Accounts, H. N. Halper, valuation engineer, Erie Railroad.

Vice Chairman of Committee 13—Water, Oil and Sanitation Service, H. M. Schudlich, engineer of water services, Northern Pacific Railway, who is sitting in for Chairman McMullen, engineer of tests and water service, Texas & Pacific Railway, who was unable to be present today.

Chairman of Committee 14—Yards and Terminals, J. N. Todd, superintendent of scales and work equipment, Southern Railway System.

Chairman of Committee 15—Iron and Steel Structures, J. F. Marsh, engineer of bridges, Chicago, Rock Island & Pacific Railroad.

Chairman of Committee 16—Economics of Railway Location and Operation, H. B. Christianson, Jr., division engineer, Chicago, Rock Island & Pacific Railroad.

Chairman of Committee 17—Wood Preservation, A. J. Loom, general superintendent timber preservation, Northern Pacific Railway.

Vice Chairman of Committee 20—Contract Forms, W. D. Kirkpatrick, assistant to chief engineer, system, Missouri Pacific Lines, who is sitting in for Chairman G. W. Patterson, assistant chief engineer, Central Region, Pennsylvania Railroad, who was unable to be present.

Chairman of Committee 22—Economics of Railway Labor, R. J. Gammie, chief engineer, Texas & Pacific Railroad.

Vice Chairman of Committee 24—Cooperative Relations with Universities, W. H. Huffman, assistant engineer of maintenance, Chicago and North Western System.

Chairman of Committee 25—Waterways and Harbors, Arthur Anderson, special assistant engineer, New York Central System.

Chairman of Committee 27—Maintenance of Way Work Equipment, N. W. Hutchison, engineer of work equipment, Chesapeake & Ohio Railway.

Chairman of Committee 28—Clearances, A. M. Weston, senior assistant engineer, Baltimore & Ohio Railroad.

Chairman of Committee 29—Waterproofing, T. M. von Sprecken, assistant to chief engineer, Southern Railway System.

Chairman of Committee 30—Impact and Bridge Stresses, E. S. Birkenwald, engineer of bridges, Western Lines, Southern Railway System.

Chairman of Special Committee on Continuous Welded Rail, L. F. Racine, chief engineer, Chicago, Indianapolis & Louisville Railway.

Gentlemen, this is your table of committee chairmen. (Applause)

The ladies seated at the large table in front of me include the wives of quite a number of our officers, past presidents and other guests. It is very nice to have you with us. I would be remiss if I did not notice the touches of color at your table, which seem to indicate unmistakably that Easter Sunday isn't very far away.

I know that all of you will be interested in the results of the balloting of the Association for its officers for the ensuing year. The official count was completed only late this morning. I will read the names of the men involved, and I would ask that they rise, be recognized, and then sit down.

(For results of elections, see Teller's Report, page 992).

President Miller: Our new officers will be installed at the business session of our convention, beginning about noon tomorrow. You are all welcome to this session if you desire to come, and that includes the ladies and any guests or supply men who may wish to be present.

Our speaker today is Mr. N. R. Crump, M. E., LL. D., Doctor of Engineering, at Montreal, Canada. Since joining the Canadian Pacific Railway at the age of 16, he has advanced from a job as laborer through the motive power and operating departments, by long strides, to the position of senior vice president and member of the company's executive committee.

Mr. Crump was raised in a railroad atmosphere, for his father, a retired superintendent, was a mountain railroader when the spiral tunnels were built by the Canadian Pacific through the Canadian Rockies. While serving his time as a machinist's apprentice in a locomotive shop, Mr. Crump realized that education was of prime importance. Finishing his high school, he entered Purdue University in 1926, receiving his mechanical engineering degree in 1929, and his master's degree in 1936 from the same school, having written a thesis on diesel locomotives. In 1950 Queens University awarded him an honorary degree, LL. D., and in 1951 he was awarded the doctorate of engineering by Purdue.

He is an honorary member of the ASME and a member of other engineering associations.

If you examine the staff records at Purdue, you will likely find that one of the technical librarians who graduated in 1929 moved across the border to see our speaker, and she became Mrs. Crump in 1930.

Mr. Crump, it is indeed a pleasure to introduce you to my friends at the Annual Luncheon of the American Railway Engineering Association. (Applause)

The Railway Industry

By N. R. Crump
Vice President, Canadian Pacific Railway

It is a very great pleasure to appear before this Association, representing as it does railway engineering opinion drawn from some 34 countries. Of course, the great majority of your membership is here in the United States, but I am glad to see over 200 members from my country—more than twice the number drawn from the 32 countries other than the United States and Canada. To me this is only proper, for where else in the world can one find such an affinity of interest as exists across the 49th parallel. I would particularly like to recognize at this point the contribution made to the transportation industry by your Association since its inception in 1899.

Your Canadian members are happy to see a countryman presiding here today, and we of the Canadian Pacific have particular pride that one of our colleagues has been so honored. I understand that George Miller is the seventh Canadian to be your president and the fourth from our company. I congratulate Mr. Miller in having won the confidence of so distinguished a group.

It has been said—and I think truly said—that the secret of the railroads' success for well over a century has been the use of a flanged metal wheel rolling on a steel rail. In view of my early training as a mechanical engineer and railway shopman, I might be suspected of being somewhat partial to the interests of the flanged wheel in the friendly rivalries that occur between the mechanical and the engineering divisions of the railway fraternity. But in recent years I have had to preside over the interests of both departments on the Canadian Pacific, and of course I have found these interests to be largely mutual rather than conflicting. In considering the problem of flange wear, for instance, what could be more mutual than the question as to whether the wheel wears out the rail or the rail wears out the wheel.

The flanged wheel and the steel rail have enabled the railways to produce mass transportation—at low cost. It is not generally realized that the railways were one of the first mass producers of the Industrial Revolution. In fact, the low-cost overland transportation provided by the railways was, and still is, absolutely essential to our mass production economy. In Canada new rail lines have recently been completed and others are under construction to serve new industries and open up new communities. For example, last year saw the completion of a 350-mile rail line from Seven Islands on the north shore of the St. Lawrence River into the iron mines of northern Quebec. This railway was built and is being operated by private enterprise to perform the big transportation job of moving overland millions of tons of iron ore annually to the waterfront for furtherance by vessel to the steel mills of this continent.

Now, the private company that built this railway could have built a highway, and instead of hauling the iron ore by rail they could have hauled it by truck. Instead of using the flanged wheel on steel rail, they could have used the rubber tire on asphalt or concrete pavement. Why didn't they? The answer is a simple matter of cost that greatly favored the rail. In the first place, the company would have had to pay for the construction and subsequent maintenance of the highway. There were no taxpayers or automobile users available to share the burden of these costs. But even if there had been, it still would have been cheaper to build the railway and get the low cost operating advantage of mass transportation that only the railway offers. The people who built and who are operating this railway could not in any sense be described as so-called "die-hard" railroaders. They were tough business men who realized they had a big transportation job on their hands that had to be performed as efficiently and as economically as possible. Their decision was based not on sentiment or tradition, but on cold economic fact. Now, if cold economic fact is a valid reason for building a new railway, surely it is equally valid as a reason for maintaining existing railways in a healthy condition where there are still big transportation jobs to be done.

The engineers who have developed the art and science of railroading may justifiably be proud of their record and of their achievemnt. You have not stood still in the past and you cannot afford to stand still now or in the future. In some quarters the railways have been described as a declining industry. I do *not* subscribe to that opinion. What is far more to the point is the fact that over the years the railways have been a *declining cost* industry; furthermore, in my opinion, we have by no means exhausted the possibilities of still greater economy and efficiency in rail transportation.

Getting back to cold economic fact, it may not generally be realized that, in terms of real purchasing power, it costs only about half as much on the average to produce a ton-mile of rail transportation as it did in 1899—the year your organization was founded. This has been accomplished by exploiting the transportation potential inherent in the flanged wheel rolling over the steel rail. Heavier and better rail, improved roadbed, more powerful and more efficient locomotives, automatic signaling, push-button hump yards, and many other technological advancements have contributed to the long record of railway progress.

Notwithstanding all this, there is a large question mark in the minds of many people as to the future of the railways. The growth of other forms of transportation and the inadequate return on investment in railway properties during a period of general prosperity and economic expansion—these conditions indicate that things are not altogether as they should be in the railway industry, or—speaking more broadly—in the transportation industry as a whole.

I should like, for a few minutes, to turn your attention to this problem which, I am bound to admit, is more of an economic than an engineering problem. However, all of us who work for railways are vitally interested in the future of these railways, since our welfare is inextricably linked with the prosperity of the industry. The initial steps toward the solution of a problem, as any engineer knows, are first a realization that the problem exists, and secondly a general understanding as to the nature and scope of the problem. In these respects there are today many hopeful signs of progressive thinking and constructive action.

Basically, the problem lies in making the transition from monopoly to competition. Many essays have been written and scholarly dissertations given on the subject. I can only touch upon what I consider the essentials from a practical standpoint—possibly at the risk of over simplification.

As to the competition, it's here and it's here to stay. There is a place for truck transport, for pipe line, inland water and air transport. As to truck, inland water and air transport, the railway industry feels that their true economic place would be better determined if they were required to pay their full share of the cost of building and maintaining the facilities they use. I do not propose to deal with this aspect of the problem other than to recognize its existence and to add that it should be taken into account in establishing conditions of fair competition between the different forms of transportation.

Competition is bound to have a big bearing on two phases of railway business: first on our pricing policies; second, on the kind of services we should be attempting to give.

As to pricing, it is common knowledge that traditionally the railway freight rate structure was characterized by what is known as differential pricing, which generally meant charging higher rates for high-valued commodities and lower rates for low-valued commodities. Truck competition has imposed a ceiling on the rates the railways can charge for high-valued commodities and still secure the business. It is often said that trucks get the business because they give better service, but you cannot disassociate price from service. If there is a difference in service, there should be a corresponding difference in price—just as there is a difference in price between a made-to-measure suit and a ready-made suit.

The real significance of this is that the railways cannot expect to recover as large a proportion of their constant and overhead expenses from high-valued commodities as they have in the past. This will be true whether the railways reduce their rates on truck competitive traffic or whether they leave the trucker under the protection of the railway price umbrella and let him have the more lucrative traffic. It seems reasonable to assume that in the long run the railways will be better off by retaining and regaining all the traffic upon which they can make a profit, but in any case there will not be the same opportunity in the future as in the past to distribute the burden of transportation costs on the basis of value of the product carried.

This means that either the rates on low-valued commodities must be increased or the total railway expense must be reduced, or both. I do not propose to say anything more about rates except this: that in Canada we have a particularly acute problem in respect of low-rated traffic. I refer to the so-called Crow's Nest grain rates which are fixed by statute at the level of rates prevailing in 1899. As the dollar today is not worth much more than 25 cents was in 1899, this means that these grain rates, in terms of real purchasing power, are only slightly more than one quarter of what they were in 1899. These rates, which yield half a cent per ton-mile cover the movement of all grain and grain products from the Prairie Provinces to the Lakehead, and also to the Pacific Coast for export. This traffic in terms of ton-miles constitutes about one-third of Canadian Pacific total freight traffic. The rates are about one-third the level of rates for comparable movement of grain in the Northwestern States. When I tell you that these statutory rates, fixed by Parliament, are only about 27 percent of the average level of all other freight rates—as measured by ton-mile earnings—you have a rather striking illustration of differential pricing; in this case an arbitrary differential far greater than anything that could be justified in the economics of transportation.

I come now to the second aspect of railway business which is vitally affected by competition—namely, service. Here, as I see it, there are three main considerations:

1. Under competition the railways can no longer afford to operate services that don't pay.
2. The railways may have to up-grade some services in order to retain or regain profitable traffic.
3. The railway's major advantage—one might say its sole competitive advantage—lies in its ability to handle volume traffic on high-density lines at low cost. Every effort must be made to retain and enhance this advantage.

May I elaborate on these three points—just briefly. First as to services that don't pay. When the railways were a monopoly, there were many communities wholly dependent upon the railway for transportation, and the railway was under obligation to provide both passenger and freight service. This obligation was not unduly burdensome because the railway could charge enough for its other services to cover losses on poor-paying trains and thin-density lines; the railway was sure of getting whatever traffic the community had to offer; and a branch line was the only economical means of feeding a main line. Today, generally speaking, none of these conditions exist—certainly not to the extent that they did prior to the development of highways and the trucking industry. We hear a good deal about road-rail coordination. This is the place for it. Where there is insufficient volume for economic train operation it is cheaper to handle the traffic by truck and by bus. The railways should be permitted to abandon unprofitable rail services and to substitute truck and bus services where needed either to provide local transportation or to protect the interests of the railway as a low-cost carrier dependent upon volume for its economy and efficiency.

My second point was the improvement of some services in order to retain or regain profitable traffic. Much has already been done in this connection through the operation of fast merchandise trains. There still remains the problem of matching the high-priority traffic with the high-priority symbol trains. It should be recognized that priority trains increase transportation costs. The cheapest way to handle freight cars would be on a first-in first-out basis with every train as long and as heavily loaded as the power, the sidings and the yards would permit. Probably no single factor has contributed more over the years to low cost rail transportation than the old operating rule of adhering as closely as possible to maximum rating. On the other hand, because some classes of traffic demand better service than others and because competition for some classes is keener than for others, it has been considered expedient and good business to try to accommodate these classes in fast freight trains operating on regular close schedules. Where the rates on the competitive traffic are high enough to warrant the increased cost of superior service, then obviously the higher cost trains are justified to handle the higher class competitive traffic.

There might appear to be some conflict between this and my third point that every effort should be made to retain and enhance the railway's major inherent advantage, which is its ability to handle volume traffic on high-density lines at low cost. The point at which cost considerations outweigh service considerations is a matter of judgment supported by experience, testing and analysis. It depends, of course, on how much value the customer attaches to superior service and how much it costs the railway to give it. Neither of these factors can be measured precisely.

Under competition, management decisions as to pricing and service become more difficult because the factors involved are more complicated. To deal effectively with these problems, railway management needs more freedom. The rigidities of the past must give way to greater flexibility. The transition from monopoly to competition presents problems not only for management. It requires modification of thinking and attitude on the part of public authorities, organized labor and the public at large. In our free enterprise system, we welcome competition. In theory at least, competition, provided it is fair competition, results in labor, capital and land being used where they can best satisfy the demands of consumers. This being the case, the future scope of each of the forms of transportation will depend on how efficiently it can operate and how successfully it can produce the kinds of transportation the public wants at prices the public is willing and able to pay. In brief, the very existence of competition makes it imperative that natural economic factors be taken into account by regulatory authorities, by management and by organized labor. The national economy, in the long pull, will be better served if we all work with these forces rather than against them. In the process there may be some painful adjustments here and there, but these are prices we pay for the benefits of competition and free enterprise.

You may wonder why I have dealt with this subject as I have. When I studied engineering I was taught there were four M's in engineering—Men, Machines, Materials and Methods. Since leaving the field of pure engineering I have found there is a fifth—Money. Unless our industry is prosperous you as engineers cannot obtain the capital and maintenance money to do the work you know should and must be done. If, in some measure, my remarks have confirmed and strengthened your confidence in the future of the railway industry and the role of the engineering profession in that future—then I am content.

President Miller: Mr. Crump, the careful attention and loud applause which have greeted your address indicate more clearly than I can how everyone has enjoyed hearing you. I am sure that this group of railway people understands and agrees with your message.

On behalf of the American Railway Engineering Association, I wish to thank you for taking time out from your busy life to address this group of railway engineers and their guests. (Applause)

And now, before I dismiss the Annual Luncheon, may I ask that all of you remain in your places until the ladies have left the room.

The annual meeting of our Association will be resumed at two-thirty in the Red Lacquer Room. We have along but interesting program for the remainder of the afternoon, and I urge that you assemble promptly. This Annual Luncheon is now dismissed.

(The luncheon was dismissed at 2:25 p.m.)

Afternoon Session—March 16, 1955

(The meeting reconvened at 2:35 p.m., Vice President G. M. O'Rourke presiding.)

Vice President O'Rourke: We are getting started a little late, so I would appreciate it if the members of Committee 27—Maintenance of Way Work Equipment, would come to the platform promptly.

Our first report this afternoon is that of Committee 27—Maintenance of Way Work Equipment, of which N. W. Hutchison, engineer of work equipment, Chesapeake & Ohio Railway, Barboursville, W. Va., is chairman.

Again, we would like to invite discussion and questions from the floor. These hand mikes are available, and the young man sitting right here will hand it to you if you have anything to say.

Discussion on Maintenance of Way Work Equipment

(For report, see pp. 511-555.)

(Vice President G. M. O'Rourke presiding.)

Chairman N. W. Hutchison (Chesapeake & Ohio): Those of you who have read Bulletin 519 will find Committee 27's report on pages 511 to 555, incl. We are reporting on 8 assignments, 1 of which contains Manual material, 2 of which are progress reports, and 5 of which are final reports. Seven of the 8 reports are submitted as information only.

The presentation of these reports will be confined to brief summaries, but we feel that those who are interested in work equipment will find much of value in the reports, and suggest that they be read in their entirety.

This committee solicits pertinent questions from the audience. We modestly admit that, either individually or collectively, we do not know nearly all there is to be known about work equipment, but the subcommittee chairmen will each do his level best to answer any questions you might wish to ask.

Assignment 1—Revision of Manual, was presented by Committee Chairman N. W. Hutchison (Chesapeake & Ohio).

Chairman Hutchison: There is nothing to be reported under this assignment this year.

Assignment 2—Motor Cars, Trailer and Push Cars, will be presented by Subcommittee Chairman M. E. Kerns, superintendent, maintenance of way shop, New York Central System, Jackson, Mich. This report covers Manual material, and thus will be read verbatim from Bulletin 519, page 513.

Assignment 2—Motor Cars, Trailer and Push Cars, Collaborating with Signal Section, AAR, Committee 10, was presented by Subcommittee Chairman M. E. Kerns (New York Central).

(Mr. Kerns read the report of the subcommittee, page 513 of Bulletin 519.)

Mr. Kerns: I would like to make a motion that this be adopted for publication in the Manual.

Vice President O'Rourke: Do I hear a second?

(The motion was regularly seconded.)

Vice President O'Rourke: It has been moved and seconded that the axles and end nuts, wheels and bushings described on page 513 and shown on Figs. 13, 14, 15 and 16, be adopted as Manual material. Is there any discussion? Has anyone any questions? If not, are you ready for the question?

(The motion was put to a vote, and carried.)

Chairman Hutchison: We should like to emphasize the fact that the next report, Assignment 3—New Developments in Work Equipment, is a continuing one. Each year an effort is made to include a brief description of all of the new and important developments in the work equipment field about which we are able to learn.

A summary of this report will be presented by the subcommittee chairman, Mr. T. H. Taylor, assistant engineer, Pennsylvania Railroad.

Assignment 3—New Developments in Work Equipment, was presented by Subcommittee Chairman T. H. Taylor (Pennsylvania).

Mr. Taylor: The assignment "New Developments in Work Equipment" is a continuous one and this current report is an extension of reports published in Vols. 45, 50, 52, 53, 54, and 55 of the Proceedings. It is a progress report, presented as information, and covers new machines marketed since last year.

We have included 13 machines or appliances, 3 of which are designed primarily for use with rail laying gangs, namely: a crib reducer, which lowers ballast in the cribs to avoid fouling of the heads of tie adzers; a tie brush, which sweeps the tie surfaces ahead of the adzers; and a hydraulic spike puller, capable of being operated by one man.

Five of the newly developed machines are for use with lining and surfacing gangs, including a hydraulically-actuated track jack; a self-propelled jack-carrier used for transporting track jacks between the tamping machine and the advance track-raising gang; a split-head type, vibratory electric multiple tamper; and two track lining machines.

Two machines included in the report are designed to perform operations on rail, namely: a light-weight bonding drill, which is capable of drilling either the head or web of the rail; and a light weight, self-contained rail slotter.

A self-contained earth auger, which will bore holes to a diameter of 12 in and to a depth of 6 ft, is described in our report. It also contains material regarding a weed sprayer, especially designed for treating yards, industrial spurs, and off-track areas usually reached by hand cutting methods.

A device known as a safety crank, designed to eliminate accidents caused by cranking any type of internal combustion engine, completes the picture in this current report. Needless to say, those of you who visit the exhibit at the Coliseum, sponsored by The National Railway Appliances Association, will find much of interest in the way of new developments in work equipment.

Vice President O'Rourke: Thank you, Mr. Taylor.

It seems needless to remind you that this report is one of great importance, and must be of interest to all of you. I can't help but feel that someone must have some remarks to make on the report, or some questions to put to the committee.

If not, we will proceed, Mr. Chairman.

Chairman Hutchison: The next report is Assignment 4—Improvements to Be Made to Existing Work Equipment. This will be summarized by Mr. L. E. Conner, supervisor of work equipment of the Seaboard Air Line Railway, who has capably served as chairman of this subcommittee for several years.

Assignment 4—Improvements to Be Made to Existing Work Equipment, was presented by Subcommittee Chairman L. E. Conner (Seaboard Air Line Railroad).

Mr. Conner: This is a progress report, submitted as information, being a continuation of reports submitted by this committee in previous years, and covers changes in existing work equipment that the committee has found to be both desirable and practical.

The current report is confined to several improvements which we suggest be made to a machine designed for placing rail in track from the roadbed shoulder, and two improvements to a machine known as a ballast regulator.

In confining our report to these two machines, we should like to emphasize that there is no intention to insinuate that these are the only two types of work equipment that can stand improvement, nor were they singled out for special criticism. With due respect to the machine manufacturers who, the committee feels, perform a highly creditable job in designing and fabricating efficient machines to perform rough types of work under sometimes very unfavorable conditions, it goes without saying that the perfect machine has not yet been built. In order to keep the report brief, it is customary to confine our remarks to just a few of the machines about which controversies arise.

Vice President O'Rourke: Again, it seems that a subject of such importance and timeliness should call for some comment from someone.

If not, we will proceed. Thank you, sir.

Chairman Hutchison: One of the most recently developed types of work equipment, and one about which there has been considerable activity in recent years to design a practical unit, which would also produce savings, is a machine for renewing ties. This next assignment is on tie renewal equipment, and, in the absence of the subcommittee chairman, this report will be presented by Mr. A. W. Munt, supervisor work equipment, Canadian Pacific Railway. I should also like to say that Mr. Munt is vice chairman of this committee.

Assignment 5—Tie Renewal Equipment, was presented by A. W. Munt (Canadian Pacific), committee vice chairman, in the absence of Subcommittee Chairman L. B. Cann, Jr., (Richmond, Fredericksburg & Potomac).

Mr. Munt: It is the hope of your committee that through this report you will be able to find a description of the tie renewal equipment that is available and possibly find the machine that will meet the needs on your railroad.

Your committee has covered 11 pieces of equipment used in some form for the removal or insertion of ties in track. Two of these pieces of equipment now being used are the companion tools—Tie Remover and Tie Replacer. Basically, each is a manually operated jack which, when attached to a rail, may exert a horizontal force via a rack bar. The operation of the tie remover must be prefaced by removal of the tie plates, ballast loosened at both ends of the tie, and ballast removed level with the bottom of the ties. Another tool, the Tie Pusher is designed to remove old or defective ties from the track. Again, the tie plates and spikes must be removed beforehand. After the old tie is pushed out by leverage, the crib must be cleaned and the new tie installed in the normal manner.

The first of the machines covered in this report is the Tie Puller and Inserter, a new machine designed for use in out-of-face tie removal and track raising. This is a combination tie remover, inserter and light crane. Essentially, this machine is a 4-wheel frame with a power winch and telescoping boom. It is found working in mechanized tie renewal gangs on many of our roads.

The Tie Cutter and Tie End Remover work in conjunction with each other. The Tie Cutter is used to saw ties in track into three sections. The center section is removed by hand, and the Tie End Remover pushes the two end sections clear of the rail by two hydraulic pistons and are lowered into the space where the center section was removed.

A hydraulic tie puller and inserter and hydraulic jack, known as the Tie Replacer, has been combined by one manufacturer. The tie renewal gang uses it to remove the old ties from their position under the rail and to insert the new tie. This unit is hydraulically controlled and self-propelled.

The Tie-Master is a machine designed to remove the old tie, cut the bed for the new tie, and install the new tie in a series of continuous operations. The primary part of this machine is a flexible chain ram consisting of a series of flat plates which cuts the bed for the new tie as it pushes out the old tie.

Two hydraulic machines used in tie renewal work are the Tie Remover and Tie Inserter. To remove a tie the Tie Remover is set squarely over the tie, and a ram, with two teeth, bites into the tie. As the hydraulic pressure is exerted a maximum force of 16,000 lb is developed in pushing the ties from under the rails. New ties are drawn into place by a cable fastened to a drum, with the middle loop hooked over the far end of the tie. Before insertion, the near end of the tie is fitted with a nose plow and the far end with a tie shoe. This shoe has a groove for the cable and a handle to guide the new tie into place.

The Tie Renewal machine is a compact one which removes the old tie by pulling it through two revolving gripping rollers. These rollers are hydraulically raised and lowered into position and their distance apart is so regulated that they can extract ties of various width.

The last machine I wish to mention is the Tie Bed Scarifier. It can perform on track that has been raised on the bed, or on non-raised track. As the hydraulically controlled drums roll, a new tie bed, perpendicular to the rails and 10 ft long, is dug to a predetermined depth.

Vice President O'Rourke: Thank you, sir.

I can't help but feel that there are people in this room who, like myself, may be a little surprised at the large number of tie renewal machines that have come on the market in the past very few years. Certainly, something is going to be developed that will be a satisfactory tie renewal machine. Up to the present time there have seemed to be some little "bugs" in every one of them.

Are there any questions or is there discussion on this subject? If not, we will proceed.

Chairman Hutchison: The fact that automotive vehicles for the transportation of men and materials are quite common on many railroads has made it important that this committee report on various features concerning such equipment. This current report on Assignment 6—Maintenance of Automotive Vehicles, deals with measures that may be adopted to minimize the breakdowns to automobiles, and will be presented by Mr. C. F. Lewis, superintendent work equipment of the Santa Fe.

Assignment 6—Maintenance of Automotive Vehicles, was presented by Subcommittee Chairman C. F. Lewis (Santa Fe).

Mr. Lewis: There are many and varied opinions on preventive maintenance, and volumes can be written on the subject. It is, however the opinion of this committee that preventive maintenance is a means for the systematic detection and correction of incipient vehicle failures before they occur or develop into major defects, and maintains vehicles in a satisfactory operating condition.

It has been said that no automotive vehicle is in perfect operating condition, but that these imperfections are often not detectable and are the cause, either directly or indirectly, of many major breakdowns. While a thorough and well organized system of preventive maintenance will not always detect these defects, generally speaking, they will be noticed and can be corrected before a major breakdown occurs.

Any good workable program of preventive maintenance must start with the operator of automotive equipment if the program is to be carried through to a satisfactory conclusion. While it would be desirable to have a competent automotive inspector check vehicles periodically, and have competent repairmen to make the necessary repairs, it must be understood that the main link in any good chain of preventive maintenance is the education and indoctrination of individual automotive vehicle operators with a complete understanding of the operation of their particular piece of equipment, as well as with the constant care, servicing and inspection it requires.

Generally speaking, if a vehicle is properly lubricated; if the air and oil filters and crankcase breathers, as well as the machine itself, are kept clean; and if defective parts are promptly replaced; the possibility for automotive failures will be minimized. Likewise, if all bolts, nuts, screws, etc., are kept tight, breakage and excessive wear from vibration will also be minimized. When minor defects are noted and immediately corrected they cannot develop into major automotive breakdowns.

If an operator takes adequate care of his vehicle; if the vehicle is given regular and periodic inspections; and if all repairs are handled systematically and correctly; any good program of preventive maintenance will result in long trouble-free service.

Vice President O'Rourke: Mr. Lewis, I presume this report is for information?

Mr. Lewis: That's right.

Vice President O'Rourke: Is there any discussion from the floor?

It will be received as information. Thank you, sir.

Chairman Hutchison: The prominence reached by machines available for out-of-face track surfacing, and work incidental thereto, has raised questions by some railroad officers as to what machines or appliances, if any, are useful for handling ballast. Assignment 7—Machinery for Unloading, Distributing and Dressing Ballast, is an attempt to answer these questions, and this report will be presented by the subcommittee chairman, Mr. J. W. Risk, superintendent work equipment of the Canadian National Railways.

Assignment 7—Machinery for Unloading, Distributing and Dressing Ballast, was presented by Subcommittee Chairman J. W. Risk (Canadian National).

Mr. Risk: In recent years there has been a trend toward the use of large, highly-specialized gangs to perform out-of-face track surfacing, this trend having arisen as a result of the development of high-production multiple tampers and other allied machines which assist in the completion of heavy surfacing programs. Since ballast is the principal material used for track surfacing, better methods of handling ballast are a requirement if such gangs are to reach and maintain peak efficiency. A search for better methods of ballast handling prompted the decision to undertake this assignment, and the report being presented is an attempt to acquaint railroad officers with the equipment and devices which are currently available.

This report covers ten machines or methods which are being used to unload, distribute, and dress ballast, the majority of which are not new, such as spreader-ditcher cars, special ballast cars, hopper-bottom cars, general purpose cars, air-operated side dump cars, lidgerwood cars, and ballast unloading pans. In the past few years practical machines have been developed which perform a creditable job of repositioning ballast after it has been unloaded, and in dressing the ballast after the surfacing work has been completed. However, most of the devices or methods used to unload ballast are slow and unsatisfactory. It is the opinion of your committee that there is a real need for special ballast cars, or for some device which can be quickly applied to existing hopper or gondola cars, and which will permit ballast to be unloaded quickly and economically, with controls that will permit it to be placed where wanted in the varying quantities needed.

Vice President O'Rourke: This is a splendid report, and I hope that there will be some discussion from the floor.

If there is none, we will proceed, Mr. Chairman.

Chairman Hutchison: Coincident with the increasing use of automobile trucks for hauling men and material is the use of platform-type trailers for transporting work equipment, which are pulled along the highway by a truck and make it possible, within limitations, to get men, material, tools and equipment to a job at the same time, ready to go to work.

In the absence of the subcommittee chairman, Mr. S. E. Tracy, superintendent of work equipment of the Burlington, will briefly tell you in this next report what types of automotive trailers are available for transporting work equipment.

Assignment 8—Automotive Trailers for Transporting Work Equipment, was presented by S. E. Tracy (Burlington) in the absence of Subcommittee Chairman C. T. Blume (Frisco).

Mr. Tracy: Railway ownership and use of automotive trailers for transporting work equipment are moderate, but the potential is evident.

The standard types are generally adaptable to the service of transporting work equipment and will normally effect reduced railway ownership cost that would not be realized normally in respect to specially designed units.

There are two general classes of trailers. These are the semi-trailer and the trailer. The general classes may be divided into numerous subclasses suitable for transporting work equipment on the railways.

Standard units are available in many sizes and with capacity ratings of less than 1000 lb to and exceeding 125,000 lb gross vehicle weight. Special permits are to be obtained in all cases wherein the size and weight exceed the ordinary authorized limits for movement on the highways of the states involved.

The pneumatic tire semi-trailer is more maneuverable than the trailer and is not restricted by any state law. The trailer, or full trailer, is illegal in certain states and legal operation is subjected to change as laws are enacted periodically by the states.

The capacity of the semi-trailer type is not affected to the same extent as trailers by increased rates of highway travel, and the semi type is far more adaptable to general service requirements.

Power brakes are recommended for all units, irrespective of weight or the state's minimum requirement, although there are states that are rather lenient in trailer brake requirements.

The adaption of highway vehicles generally by the maintenance of way departments of the railroads should obviously increase the demand for automotive trailers for transporting work equipment.

Vice President O'Rourke: Thank you, Mr. Tracy.

If there is no discussion from the floor, it will be so received.

Chairman Hutchison: No report is offered under Assignment 9—Means of Conserving Labor and Materials. This has been a continuing assignment, and a report was presented for several years. This committee feels that insufficient additional data can be collected to prepare a report, and a request was made—and granted— that the subject be discontinued.

In view of the fact that we have probably exceeded our allotted time, and also because the summary of the next report contains adequate introductory comments in itself, we will ask Mr. Knight, supervisor of work equipment of the Northern Pacific Railway, to proceed with his report on the subject of Work Equipment Hydraulic Systems.

Assignment 10—Work Equipment Hydraulic Systems, was presented by Subcommittee Chairman S. H. Knight (Northern Pacific).

Mr. Knight: Hydraulics is not a non-technical subject. However, our assignment is not concerned with technical matters, but solely with the practical aspects of hydraulics as commonly used in railroad work equipment transmissions. Our coverage further does not include fluid clutches or torque converters. We are concerned only with simple transmission systems and the prime movers, pumps, motors, and distribution pressure and return piping and valves comprising them.

Hydraulic transmissions are to a great extent, as you know, a recent development which received great impetus during the war years 1940–1945. Actually, the airplane had much to do with it. However, industry generally has adopted it, and today we find hydraulics has invaded the fields of farm machinery, railroad work equipment, construction equipment, and many others. It is difficult today to find a piece of major work equipment that does not employ hydraulics in some form as a means of transmitting power.

Its greatest use is, without doubt, in the transmission of power by means of hose line or tubing to auxilliary apparatus that may be remotely located from or inaccessible to the main source of power, which, if done mechanically, would require a complicated hook-up of sprockets, chains, gears and shafting. An hydraulic system is simple in principle, permits of great flexibility of installation, and is smooth and vibrationless in operation. The transmission may be reversed or idled by means of a simple 4-way valve, and precise control is obtained. Variation in torque ratio, speed and overload, and shock protection, are readily obtained. Some disadvantages include high thrust and radial loads on bearings, high stresses in certain other parts, the necessity for extreme accuracy of machined parts, and cleanliness in assembly, operation and maintenance. Difficult sealing problems also prevail. We have had experience with some installations which, the committee feels, could have been better accomplished by mechanical linkage.

Little has been done, however, with hydrauiic transmissions toward standardization. Further, there is a complete lack of inexpensive, readily available testing equipment by which volumetric efficiency, torque and horsepower may be determined. Some builders of machines are working on the problem, but it is still necessary for the owner to remove pumps and motors for return either to the builder or to the manufacturer to have them calibrated. We think dynamometer apparatus should be supplied which would make it unnecessary for the owner to carry spare pumps and motors without experiencing long delays awaiting return of the article from the builders' shop or from the manufacturer.

That is a serious defect. No one would think of repairing an electric motor or generator without testing it for power characteristics; nor should he repair an important gasoline or diesel engine without giving it an extended run on a dynamometer. So, we hold no brief for the lack of adequate testing apparatus for hydraulic pumps and motors that prevails today—a condition which the manufacturers of hydraulic equipment seem to be completely unconcerned about.

In conclusion, hydraulics and hydraulic transmissions are competing more and more favorably with the transmission of power on machinery by electrical, pneumatic or mechanical means. Without question, the years immediately ahead will continue to see an accelerated development in this type of power transmission.

Vice President O'Rourke: Thank you, sir. That report is submitted as information?

Mr. Knight: Yes.

Vice President O'Rourke: It is one of great importance, and I am sure the committee would welcome any views from the floor—suggestions, questions or comments. If there are none, it will be so received.

Chairman Hutchison: Mr. President, this completes the report of this committee, but before finally taking leave, I should like to call attention to a memoir which appears on page 512 of Bulletin 519, for one of our former members, Mr. C. H. R. Howe. I will not take time to read the memoir, but this committee wishes to publicly express its deep sorrow in the passing of one who was not only a valuable and highly regarded Member Emeritus of this committee, but a very fine friend of many of the men in this room.

We should also like to pay tribute to another of our retired members, Mr. C. H. Ordas, formerly supervisor of motor cars of the Milwaukee Road, who just recently passed away. Mr. Ordas was one of the hard-working members of this committee, who not only was one of its charter members, but who also held the distinction of having served actively in the railroad industry over a period of 57 years.

Vice President O'Rourke: Thank you, sir.

Mr. Hutchison, your committee has again presented a splendid series of reports, involving both Manual material and information of great interest to our membership. The automation of maintenance-of-way and construction operations is vital to the efficiency and economy of our work, and your committee does a valuable service in keeping us up to date, not only on the equipment which is available, but also as to its operation and repair.

Your committee is now excused with the sincere thanks of the Association.

The next report to come before the Association is that of Committee 22—Economics of Railway Labor. The chairman of this committee for the past three years has been Mr. R. J. Gammie, chief engineer, Texas & Pacific Railway, and I am glad to recognize him and the members of his committee at this time.

(President G. W. Miller resumed the chair.)

President Miller: Mr. Gammie, the floor is yours.

Discussion on Economics of Railway Labor

(For report, see pp. 453-469.)

(President G. W. Miller presiding.)

CHAIRMAN R. J. GAMMIE (Texas & Pacific): Mr. President, fellow members and guests of the Association: During the past year Committee 22 lost one of its valued ex-members, Mr. Charles William Baldridge, former assistant engineer of the Atchison, Topeka & Santa Fe Railway, who died in this city, May 31, 1954. A special committee on memoirs, of which M. H. Dick, editor of Railway Track and Structures, is chairman, prepared a memoir on Mr. Baldridge, which forms a part of the committee's report.

We will now hear from a member of this committee, Professor W. W. Hay, who will talk on The Engineer's Responsibility for the Future.

The Engineer's Responsibility for the Future

By W. W. Hay

Associate Professor of Railway Civil Engineering, University of Illinois

A year ago Mr. J. S. McBride gave the convention an informative and interesting description of railroad engineering and maintenance of earlier days. I have been asked to say something about railroad engineering in the future. Unfortunately, I have no way of knowing what the future holds in the way of new developments and procedures. Probably no one really knows. It I did know and told you, you might not believe me. Who would have believed 40 years ago even a small part of the modern developments in the railroad industry? Perhaps, however, more surprising than the improvements over the past are the number of practices from the past which are still retained. As we consider some of the more startling developments which we now enjoy we might, with some degree of discomfiture, ask ourselves what obvious improvements are we overlooking today!

There are, of course, some things which can be foreseen for the immediate future because they are already in the picture and will expand and develop in days to come. There will, for instance, be a continuation of mechanization in construction and maintenance procedures. Concurrent with mechanization will be an increasing use of division, region, and system gangs, with section forces abolished or relegated to simple housekeeping functions. The big gangs will be transported and housed in off-track units and their work equipment will mostly be off-track as well. Radio will aid in maintaining control over large gangs, as in rail-laying spread over a long stretch of track, and in maintaining control from headquarters.

These are changes involving responsibilities for the engineer. He must plan his programs carefully to secure the best use of men and equipment. He must devise a substitute for the pride and personal interest which spurred the old style section gangs to their best efforts. Engineering and supervisory personnel must be more familiar with the mechanical side of work equipment. This familiarity cannot be secured in already overcrowded university and college curricula. The railroads will provide their own training, perhaps by placing the junior or apprentice engineer in a work equipment repair shop for several weeks or months.

Railroad engineers are becoming increasingly aware of the need for soils engineering in the design and construction of subgrades and foundations. There is much yet to be done. Every railroad will eventually have one or more men adequately trained in soils engineering and provided with the necessary field and laboratory equipment. His recommendations will play an important part in all pertinent decisions.

The present shortage of college trained engineers, while likely to improve somewhat, is also likely to continue for several more years if conditions of peace prevail; the problem will become acute if the cold war grows hot. There will be an increased demand for trained engineers in the future throughout industry. Railroads must make an even greater effort than in the past or present to secure their share of the top-ranking engineering graduates and to use most effectively the ones they have. A majority of the labor force will be composed of machine operators and mechanics. Responsibility will rest with the supervising engineer to secure, train, and retain this skilled group of labor.

The needs of national defense must ever be a major responsibility for the engineer. He must hold both himself and the track and structures entrusted to his care in constant readiness for a demand we pray will never come. If it does come, its urgency will supersede all their problems and activities for a long time to follow.

This may be wishful thinking, but I believe the future will see a significant reduction in grade crossings. As new highways replace obsolete and outmoded routes, the trend is toward an elimination of all traffic obstructions, including railroad crossings. The engineer has the responsibility to be in the forefront of any drive toward grade crossing elimination and to see that the railroads receive a fair deal in the apportioning of costs.

I see, too, the sharing of rights-of-way in congested areas by more than one type of carrier. Pipelines, and even highways, may use the same land space as railroads, perhaps the latter on a two-tier basis.

Regulatory powers of the future must surely develop a more realistic attitude toward branch line abandonment, permitting more readily the removal of trackage on unprofitable lines. Railroads will be more willing to build for short term traffic if they know they can abandon the line when that traffic dies out. There will be more improvement of location and routes—grade and curve reductions—shortening of distance and removing of tracks from flood levels. At the same time there is likely to be more retrenchment and abandonment of multiple tracks in favor of fewer tracks and systems of centralized traffic control. The engineer must be ever on the alert to realize all the economies which these activities will permit.

The use of diesel-electric locomotives should call for a searching re-examination of the present trend toward heavier track and equipment. Adverse effects of diesels should also be noted. The possible advent of lightweight Talgo-type trains affords interesting possibilities. If these trains prove successful and appear in great numbers, the engineer will encounter new problems and an opportunity to revise his standards in track and bridge design and maintenance.

Railroads and their engineers will undoubtedly place increasing dependence upon research. There isn't a phase of railroading today that cannot be improved by wise study and investigation. New materials, methods, and machines developed elsewhere must be analyzed for their application to the railroad plant and its operation. Prestressed concrete holds promise for improved railroad structures. An informed use of color will promote safety and more efficient operation. Automation is already proving its value in yard operation—and incidentally requires a high standard of yard track maintenance. Automation has possible applications to many rail operations. Railroads will expand their own testing and investigative facilities and will become increasingly aware of their responsibility to use and to support, financially and otherwise, the facilities and findings of research agencies. The program of engineering research being so ably conducted by the Association of American Railroads in cooperation with this Association is an important and worthwhile step in that direction.

This limited and brief listing could be expanded if time permitted. But now, what of the over-all scope of the engineer's responsibility for the future? The forecast can be made with a fair degree of certainty.

The railroads' chief competitors are relative newcomers to the transportation industry. They have already demonstrated their dynamic character and will continue to develop and improve in the years to come. It follows that railroads will continue to face stiff competition in the future which, in turn, will impose a responsibility on the engineer for the utmost efficiency, safety, and economy in the conduct of his work.

These cannot be accomplished by thinking in terms of present practice or by the mere improvement of existing procedures and materials. Mechanization alone will not be sufficient. The law of diminishing returns on mechanization as we now know it will eventually take effect.

It is not sufficient for the engineer to devise new and better ways of doing conventional tasks. He must seek to eliminate many of the tasks he is doing today. He must learn to look at every phase of plant and operation with a critical, questioning attitude. If a large percentage of track labor costs are due to joint wear and maintenance, then he must eliminate the joint. If tie renewals are a costly item, he must eliminate the need for those renewals. Rail renewals due to shelling, web failures, and rolling defects must—and will be—eliminated, and rail life prolonged far beyond what it now is. If subgrades are unstable, the engineer must eradicate the causes of instability. These examples are merely illustrative and are certainly not startling. A beginning has already been made on these problems—but there are also other problems!

To bring about such attitudes and improvements the engineer must have an open mind and be receptive to new ideas. He must have the courage to advocate and defend his ideas, sometimes against a firmly entrenched conservatism and standpatism. He must not let current standards and practices become a strait-jacket for the future. Any individual or industry that spends more effort resisting change than in developing new ideas stagnates and cannot survive. It is the engineer's responsibility to advise management as to the proper direction and decisions in that part of the railway activity in which he is an expert.

The engineer must, however, have personal and professional integrity and perspective, and be as willing to discard new but unproductive innovations as old, outmoded systems. He must not confuse mere change with progress. Neither can he be misled by out-of-pocket or immediate savings. He must be guided by the principle of over-all economic costs, having in mind the full effect and long-term view as he makes his decisions. The engineer has these responsibilities for the future. If someone says these are not new responsibilities, I will readily agree. These have always been the engineer's responssibilities and his challenge. He must meet that challenge, realizing that the future begins today!

Chairman Gammie: Thank you, Professor Hay, for that very interesting and challenging talk.

The report of this committee begins on page 453 of Bulletin 519, and if there is any discussion from the floor, we will be glad to hear from anyone. This committee was assigned eight subjects for study during the current year, and has no report to make on three of these subjects.

Assignment 1 is Revision of Manual. We have no report to make on that.

Assignment 2 is an analysis of operations of railways that have substantially reduced the cost of labor required in maintenance of way work. The report on this is a progress report, and will be presented by Mr. J. E. Eisemann, district engineer, Gulf, Colorado & Santa Fe Railway, at Galveston, Tex.

Assignment 2—Analysis of Operations of Railways That Have Substantially Reduced the Cost of Labor Required in Maintenance of Way Work, was presented by Subcommittee Chairman J. E. Eisemann (Gulf, Colorado & Santa Fe), who read extracts from the subcommittee's report.

President Miller: Thank you, Mr. Eisemann. Your report will be received as information.

Chairman Gammie: I believe Mr. Geyer has a few remarks to make. He is a past president of the Association, as you all know. At the time we planned our recent inspection on the C & O, he was vice president in charge of construction and maintenance of that railway, but he retired before we made the trip. Mr. Geyer.

C. J. Geyer (Retired vice president—construction and maintenance, Chesapeake & Ohio): Mr. President, Mr. Gammie and gentlemen: It has been my pleasure for several years past to accompany this committee on its summer inspection trip over some part of some railroad, as a guest of the committee. Mr. Gammie asked me if I would care to tell the Association something about the things we have been doing on the C & O, which the committee witnessed on its inspection trip last year.

For several years, on the Chesapeake & Ohio, our maintenance boys had been studying methods and means to save on labor costs, particularly in view of the rapid advance in wages. We have two or three members on Committee 22, and the committee's studies were along the lines that we were making. We studied its reports and its inspection trips closely, and as a result, we revised our track maintenance methods.

We started this in 1951, I believe, and we are not through yet, although we have done much on the Chesapeake Region, or the Southern Region as it is now called. We expect to get going on the Northern Region a little later. I don't mean to say we are through on the Southern Region. But we are through with the first stage of the job on this region, and the payroll savings brought about by our new methods have amounted to more than five million dollars—with a little better quality of track work performed.

I think I can support the statement that the quality of the work is a little better, because we have two ways of measuring it. The first is the amount of material used, the amount of work performed, the miles of track surfaced, the number of ties installed, the tonnage of rail laid, the amount of ballast applied, etc. The second check on quality of work is our track inspection machine, which graphically records the imperfections in track as we operate over the track, twice a year. We have used the same method of grading our track since we first operated this machine, in 1937. Thus we have been able to determine which way we are going in our track conditions.

Now, I don't believe that we have scratched the surface in the savings that we have been able to accomplish through the good work of this committee. But I want to give full credit for the accomplishments that we have made to this committee work, and the ability of our maintenance boys on the Chesapeake & Ohio to interpret and use those methods recommended by the committee.

Our methods can be called several things—district maintenance, division maintenance, system maintenance, or something else. But the idea is the same—to reduce our costs and still do all the work that is needed, and have good quality work.

I hope to take many more trips with this committee. I recommend to the members of the Association and to other railroad maintenance men that they study its reports carefully.

In my opinion, more professors of economics in our colleges should get on the committee. I am sure they can add materially to the work of the committee. At the same time, I am sure they will get much good from the work of the railroad members of the committee, that they can take back to their classrooms.

Thank you very much, Mr. Gammie. (Applause)

CHAIRMAN GAMMIE: Thank you, Mr. Geyer.

Is there anyone else who wishes to say anything at this point?

PRESIDENT MILLER: Mr. Chairman, I would like to say that where railway managements help our committees travel over their roads, those railroads cannot help but benefit. I am sure that any railroad that gives a committee a chance to work on its property will benefit much more than the amount it spends in extending its hospitality in transporting the men over the line. I think the C & O really set a fine example last year. I had an opportunity to accompany the committee, and I thought it was fine. We learned a lot, and I know that a number of the features we witnessed there will be put into effect on my own road.

CHAIRMAN GAMMIE: Mr. President, we appreciate your remarks. The C & O certainly did a good job of taking care of us.

Assignment 3 is Economics in Railway Labor to Be Derived from the Use of Various Types of Ballast, Collaborating with Committee 1. This is a final report, submitted as information, and will be presented by the chairman of that subcommittee, Mr. A. B. Chaney, assistant chief engineer system—maintenance, Missouri Pacific Railroad.

Assignment 3—Economics in Railway Labor to Be Derived From the Use of Various Types of Ballast, was presented by Subcommittee Chairman A. B. Chaney (Missouri Pacific).

MR. CHANEY: I will confine my remarks here to some of the highlights of the report and the conclusions reached by your committee.

This report supplements the one submitted by Committee 22 17 years ago, which can be found on page 595 of Vol. 39 of the Proceedings, for 1938. A comparison of the two reports reflects a continuing increase in preference for the smaller size ballast materials, with two-thirds of the reporting roads, representing 83 percent of the reporting mileage, giving crushed slag and stone as their first preference for ballast materials.

The service tests being made on the Chicago and North Western Railway by Committee 1 to determine the maintenance costs and service life of three different sizes of slag ballast will develop valuable data pertaining to ballast economics.

Your committee's study of information received from 40 railroads representing 65 percent of the rail mileage in the United States and Canada, prompted the following conclusions:

For heavy and medium-heavy-traffic lines, crushed stone and slag ballast meeting AREA specifications, with maximum size of 1½ in, and uniformly graded, is the preference of most railroads, based on overall economic consideration.

For medium and light-traffic lines, chat, and in some cases crushed gravel, are the most economical ballast materials.

Except for special requirements, most roads prefer ballast materials for general use within a size range of from ½ to 1½ in.

Definite economies in railway labor can be derived by using the most suitable types of ballast, and it is believed that individual roads can profit from a study of the subject on the basis of factors existing on their lines.

We were confronted with difficulty in developing actual cost data, but we did have a response from 9 railroads representing over 26,000 miles of main tracks, and you will find this material in the report.

PRESIDENT MILLER: Thank you, Mr. Chaney. Your report will be received as information.

F. A. Roberts (Erie): Mr. Chaney, in paragraphs 16 and 17 of Bulletin 519 you state that 14 roads report no difference in the amount of ballast required per mile per year. and that the labor costs on gravel ballast average 33 percent higher than where crushed limestone is used. I would like to know why.

Mr. Chaney: The committee tabulated the material furnished by the different railroads, and, as I recall, gravel ballast ranked about third in the preference of most railroads, with a few exceptions. The reasons given, as I recall, were that there is less friction between the ballast material and the tie, less likelihood of its staying put, so to speak, after surfacing, a greater likelihood of more difficult vegetation control, and generally, in their opinion, from their studies, gravel ballast requires more track labor to maintain the same standard of maintenance, or the standard of maintenance required.

Mr. Roberts: Thank you, sir.

Chairman Gammie: Assignment 5 is Labor Economy of Renewing Ties by Use of Proper Equipment, Methods and Organization. This is a progress report, and will be submitted as information by the chairman of that subcommittee, Mr. L. A. Loggins, chief engineer, Texas & New Orleans Railroad, Houston, Tex.

Assignment 5—Labor Economy of Renewing Ties by Use of Proper Equipment, Methods and Organization, was presented by Subcommittee Chairman L. A. Loggins (Texas & New Orleans), who read a considerable part of the subcommittee's report as printed in the Bulletin.

President Miller: Thank you, Mr. Loggins.

Chairman Gammie: Assignment 6 is Labor Economies of Various Mechanical Methods of Tamping and Equalizing Ballast, Including the Double Shifting of Machines. This report was to have been presented by Mr. Claude Johnston, division engineer of the Louisville & Nashville Railroad, but Mr. Johnston couldn't be here on account of a threatened strike on his railroad, and, therefore, we will make no report.

Assignment 7 is Comparative Economy of Handling Maintenance of Way Gangs in Trucks Versus Motor Cars, Including Economical Length of Haul, Collaborating with the Purchases and Stores Division, AAR. No report is to be submitted on this subject.

Assignment 8 is Means of Increasing or Conserving Labor Supply for the Duration of the Emergency, Advising the Secretary Currently of Recommendations or Practices that Merit Emergency Publication by the AREA. No report will be submitted, and your committee has requested the Board to withdraw this subject at the end of this year. It is being withdrawn.

Mr. President, this concludes the report of Committee 22, and also concludes my term as chairman of this committee. I would like to introduce Mr. D. E. Rudisill, the new chairman, and Mr. L. A. Loggins, the new vice chairman.

President Miller: Mr. Gammie, the Association greatly appreciated another year of valuable work on the part of your committee under your direction, and we congratulate you upon the leadership which you have brought to the work of the committee for the past three years.

We are happy to welcome Mr. Loggins as your new vice chairman, and Mr. Rudisill as your new chairman. If Mr. Rudisill will please stand, I should like to present him with a chairman's gavel as the symbol of his authority in the conduct of the committee's work for the next three years.

Mr. Rudisill, the band on this gavel reads, "D. E. Rudisill, Chairman, Committee 22, 1955–1957."

D. E. Rudisill (Pennsylvania): Thank you.

President Miller: Thank you again, Committee 22. You are excused, with the thanks of the Association.

We will now hear from Committee 1—Roadway and Ballast, of which Mr. B. H. Crosland, assistant chief engineer, St. Louis-San Francisco Railway, is chairman. Will Committee 1 please come to the platform?

Discussion on Roadway and Ballast

(For report, see pp. 677-731.)

(President G. W. Miller presiding.)

Chairman B. H. Crosland (St. Louis–San Francisco): Before starting the formal presentation of this committee's report, I have a few brief announcements I would like to make.

First of all, in January of this year, the members of this committee were shocked and deeply grieved to hear of the death of a loyal member, C. D. Turley, who had not only been a member of this committee a long time, but who had also been a member of Committee 3. It is my understanding that Committee 3 will have more to say about Mr. Turley, so I will not make any further remarks about him at this time.

Secondly, Mr. J. A. Noble, chief engineer of the Santa Fe at Amarillo, Tex., has been our vice chairman, but for personal reasons he has requested that he be relieved of those duties. We, of course, very reluctantly acceded to his desires. However, he told us he would stay with the committee and help us out with our deliberations, which makes it a little bit better.

The third announcement grows out of that. Mr. A. P. Crosley, who, as I think most of know, is engineer maintenance of way on the Reading, has been appointed vice chairman to serve out the unexpired term of Mr. Noble.

The report of this committee appears in Bulletin 521, beginning on page 677. Ordinarily, the chairmen of the subcommittees, in making their reports, will not again refer to that Bulletin. Consequently, those of you who want to follow the reports should make a note of the location of our reports now.

The reports will be presented to you generally in their proper sequence, except that one of our subcommittee chairmen must leave in about 15 or 20 min, so I am going to put him on first, so he will not miss his obligation. The report of our Subcommittee 6, introducing our speaker for today, will be held until the last.

This committee deals with 11 general assignments. We are particularly anxious to have the support, the suggestions, the comments and the criticisms of all of the members of the Association, and with that thought in mind, we would be very glad to have you get up as these reports are rendered and offer any criticisms, comments or suggestions that occur to you.

Subcommittee 1, dealing with Revision of Manual, will have no report at this time, and we will jump down the line to Subcommittee 9, on Signs. The report of this subcommittee will be presented to you by its chairman, Mr. J. E. Chubb, division engineer, Pennsylvania Railroad.

Assignment 9—Reflectorized Roadway Signs, Collaborating with Committee 9 and the Signal Section, AAR, was presented by Subcommittee Chairman J. E. Chubb (Pennsylvania).

Mr. Chubb: Subcommittee 9 of Committee 1 has been assigned the subject of reflectorized signs. At the time of this assignment it was not deemed advisable presently to include a study of or recommendations for the kinds of roadway signs which should be reflectorized. Accordingly, the committee's assignment for study and report has been limited to types of reflectorized signs and methods of applying reflectorizing materials to roadway signs.

This study has been made by your committee in collaboration with Committee 9—Highways, and to conform with related specifications of the Signal Section of the AAR. The committee intends to continue its study during the present year.

Mr. President, this progress report, as published in the Bulletin, is presented as information.

President Miller: Thank you, Mr. Chubb. This report will be so received. It is a very timely one.

Chairman Crosland: The next report is by Subcommittee 2 on Physical Properties of Earth Materials, to be presented by its chairman, Mr. R. R. Manion, chief engineer, Great Northern Railway.

Assignment 2—Physical Properties of Earth Materials: (a) Roadbed. Load Capacity. Relation to Ballast. Allowable Pressures. (b) Structural Foundation Beds, Collaborating with Committees 6 and 8, was presented by Subcommittee Chairman R. R. Manion (Great Northern).

Mr. Manion: Last year your committee submitted under Assignment 2 (a) and (b), Physical Properties of Earth Materials, new tentative material for publication in the Manual to supersede the material now appearing there. It therefore now recommends the withdrawal of the present Manual material, pages 1–1–38 to 1–1–44, incl., and the substitution, under the same caption, of the material which was published in Vol. 55, 1954, pages 616 to 628, incl.

I move that this material be adopted for publication in the Manual.

(The motion was regularly seconded.)

President Miller: Is there any discussion?

H. M. Booth (St. Louis–San Francisco): The statement is made that clays are usually very unstable in the presence of water, and should be avoided where possible. I would like to know how this can be recognized as clay before we get into it.

Mr. Manion: Montmorillonite is a term applied to the general class of material you will find in clays in certain territories. It goes under other names. In some locations the best way, of course, or the most exact way, is to have it analyzed, and I think the soils engineer would do this by determining the liquid limit of the material. The practical railroader out in the field probably recognizes it. He ordinarily has lots of it where it occurs generally in his roadbed, and it can be quickly recognized by the fact that it swells when it absorbs moisture.

Does that answer your question, Mr. Booth?

Mr. Booth: Yes.

(The motion was put to a vote, and carried.)

Chairman Crosland: The next report is by Subcommittee 3—Natural Waterways: Prevention of Erosion, and will be presented by its chairman, Mr. L. H. Jentoft.

Assignment 3—Natural Waterways: Prevention of Erosion, was presented by Subcommittee Chairman L. H. Jentoft, engineer maintenance of way, Erie Railroad.

Mr. Jentoft: This is a progress report covering prevention of bank erosion in natural waterways of the alluvial type by the use of steel jetties.

There are three different types of construction reported on. The results and benefits of each are about the same.

These types of construction have been used extensively on the Santa Fe and other western and southwestern railroads where this alluvial type of stream prevails to a large degree. The Corps of Engineers of the U. S. Army and the Bureau of Reclamation have also used and reported on these types of construction.

Photographs and sketches accompanying the report make it very easy to read and understand. It is recommended that you read this report and familiarize yourself with its contents as information.

I wish at this time to thank Chief Engineer Noble of the Western Lines of the Santa Fe for his assistance in furnishing a great deal of the information that was so valuable in preparing this report.

President Miller: Thank you, Mr. Jentoft.

Chairman Crosland: Subcommittee 4—Culverts, will now present its report, which will be given to you by its chairman, Mr. G. B. Harris, assistant engineer, Chesapeake & Ohio Railway.

Assignment 4—Culverts. (a) Conditions requiring head walls, wing walls, inverts and aprons and requisites therefor, (b) Specifications for high-pressure gas lines, (c) Methods for installing culverts inside of existing culverts, was presented by Subcommittee Chairman G. B. Harris (Chesapeake & Ohio).

Mr. Harris: Subcommittee 4 reports this year on two of its three assignments, (b) Specifications for high-pressure gas lines, and (c) Methods for installing culverts inside existing culverts.

Last year the Association approved for publication in the Manual, Specifications for Pipe Line Crossings Under Railway Tracks, Sec. A. For Flammable Substances. Under its Assignment 4 (b), your committee has prepared a tentative Sec. B. For Non-Flammable Substances, of the same specifications. This section is now presented for the purpose of soliciting comments and criticism prior to submission in 1956 for adoption and inclusion in the Manual in place of the current Sec. B. For Non-Flammable Substances.

The specifications being presented this afternoon were first presented to the Association in 1941 and have not been revised since that time until the present draft was prepared. The principal changes have been made in order that Sec. B will conform, insofar as is practical, with Sec. A, which was approved last year.

This is a progress report submitted as information.

President Miller: It will be so received.

Mr. Harris: Under Assignment (c) Methods for Installing Culverts Inside Existing Culverts, your committee, last year, presented a progress report as information. This year, the same report, with slight editorial changes, is submitted for adoption and publication in the Manual.

Many old structures have been economically rehabilitated by lining with new culvert material, and in many such cases it is possible to salvage the existing material. The report deals with the methods of installing such linings, outlining the necessary requisites for preliminary survey and study of the existing structure, and also describing the various types of lining material, their proper selection, and methods of installing same. Finally, the report covers in some detail the subject of backfilling, both materials used and methods of placing.

It is planned to insert this material in Chapter 1 of the Manual at the end of Part 4—Culverts.

Mr. President, I move that the report submitted under Assignment 4 (c) be adopted for publication in the Manual.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. Harris: In 1953, Committee 1 recommended, and the Association approved, the deletion of the adhesion test from the Specifications for Bituminous Coated Corrugated Metal Pipe and Arches. It has now been brought to the attention of the committee that a reference to this test still remains in the specifications in the last sentence on page 1–4–16. Inasmuch as prior approval of the Association has been given, we asume that the secretary's office can take care of the necessary correction when issuing the 1955 Supplement to the Manual, without further action by the convention.

President Miller: That will be taken care of as an editorial change.

Mr. Harris: Mr. President, this concludes the report of Subcommittee 4.

President Miller: Thank you, Mr. Harris. That is a very complete report, and I am sure the industry will benefit greatly by the new specifications which this committee has prepared.

Chairman Crosland: Subcommittee 7—Tunnels, will not report at this time. However, we have been requested by several railroads to furnish specific information about ventilation in long tunnels with diesel operation, and the subcommittee is assembling material on that subject, and expects to have a progress report, or preliminary report, for publication this year.

We now come to Subcommittee 8—Fences. This report will be presented to you by Subcommittee Chairman H. G. Johnson, assistant engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad.

Assignment 8—Fences: Critical Review of All Methods of Preventing Snow Drifts, was presented by Subcommittee Chairman H. G. Johnson (Milwaukee Road).

Mr. Johnson: Last year your committee presented as information, in Bulletin 514, for the purpose of soliciting comments prior to submission for adoption and inclusion in the Manual, a report consisting of three parts, namely;

Part 1—Methods of Protecting Against Drifting Snow and Opening New Blockades.

Part 2—Specifications for Wood-Slat Portable Snow Fences.

Part 3—Methods of Protection Against Drifting Sand.

Mr. President, as no comments or criticism have been received, I move that all of the material herewith presented be adopted and published in the Manual.

President Miller: Is there a second?

(The motion was regularly seconded.)

President Miller: Is there any discussion?

(The motion was put to a vote, and carried.)

Mr. Johnson: That concludes the report of this subcommittee.

President Miller: Thank you. I think it is purely coincidental that the man who presented the material last year had the name, Johnson, and the man who presented it this year also has the same name. They were two different people.

Chairman Crosland: The next subcommittee is No. 10—Ballast. The report will be rendered by its chairman, Mr. J. P. Datesman, engineer of track, Chicago & North Western System.

Assignment 10—Ballast. (a) Tests, (b) Ballasting Practices, (c) Special Types of Ballast, was presented by Subcommittee Chairman J. P. Datesman (Chicago and North Western).

Mr. Datesman: Your committee submits as information a report under assignment (a) Tests, in two parts. I shall report first on Part 1.

In July 1954, test installations of 1 mile each of 3 different sizes of slag ballast were made by the Chicago & North Western Railway in centralized traffic control territory on its north, or No. 2, main line between Maple Park and Cortland, Ill., which are located approximately 50 miles west of Chicago on the main line between Chicago and Omaha, Nebr. Ballast was placed under new 115-lb rail that was welded into lengths of 78 and 117 ft.

The installation was made to determine, under actual traffic conditions, which size ballast would give the greater serviceable life. The three different sizes of ballast placed were AREA No. 3, sizes 2 in to 1 in; AREA No. 4, sizes 1½ in to ¾ in; and AREA No. 5, sizes 1 in to ⅜ in.

Information pertaining to serviceable life, based on yearly observations, together with necessary maintenance costs for each type of ballast in place, will be furnished to this committee and collaborating Committee 22.

Part 2 is the second progress report on oscillator ballast test now in progress at the Association of American Railroads Research Center. The tests were set up primarily to determine the durability and stability of various types and gradation of ballast material. To date tests have been completed on four ballast materials consisting of crushed limestone 1½ in to ¾ in nominal size; crushed air-cooled blast furnace slag 1½ in to ¾ in nominal size; gravel 41 percent crushed particles, corresponding to AREA Gradation G–3; and chat ballast, which has 100 percent passing the 1½-in screen and 12 percent passing the No. 4 screen.

Further details on these tests, of course, are outlined in Bulletin 521, but to date the number of samples tested is not sufficient to permit any pertinent conclusions to be drawn.

President Miller: Thank you, Mr. Datesman. Your report will be received as information.

Chairman Crosland: The next report is that on the Chemical Control of Vegetation, by Subcommittee 11, which will be rendered to you by its chairman, Mr. C. E. Webb, assistant engineer of tests, Southern Railway System.

Assignment 11—Chemical Control of Vegetation, Collaborating with Signal Section and Communication Section, AAR, was presented by Subcommittee Chairman C. E. Webb (Southern).

Mr. Webb: The report on Assignment 11—Chemical Control of Vegetation, is in two parts. Part 1 is the fourth annual report on this project, which includes research at the University of Iowa, University of Florida, and the University of Montana. Part 2 is the second report of the field investigation on control of vegetation on various railroads by the AAR research staff.

For the purpose of this investigation, the United States and Canada were tentatively divided into seven sections, which were presumed to have approximately the same climatic conditions and vegetation.

The objective, stated briefly, is to provide information on methods by which the most weeds may be killed for the least money, recognizing the hazards that may be inherent with a particular formulation. The solution to this, however, is not simple. The varied types of vegetation and range in climatic conditions make it virtually certain that there will not be any one chemical or formulation that will be satisfactory under all conditions.

Although new chemicals offered to the railroads are investigated, the most important phase of these investigations consists of determining the most advantageous manner in which existing products may be used. Since, in many cases, there must be a compromise between desired results and the money available for control, it is hoped that the preceding and subsequent reports may aid in the selection of the most effective weed control program.

The following general observations may be made, based on this and previous reports:

(1) It appears that vegetation cannot be permanently eradicated, even by the most expensive treatment.

(2) The importance of planning and proper application cannot be over emphasized. A reduction of 50 percent in weed control has been noted if the optimum concentration of the chemical is reduced 20 percent.

(3) Postponement of weed control measures permits a build-up of vegetation, and has indicated that continuous control may be cheaper than intermittent, as well as more effective. In this connection, oils with specific characteristics at low cost have shown considerable promise in vegetation control.

It is hoped that as this work continues specific recommendations may be made for weed control in each of the seven sections in which the United States and Canada are tentatively divided. These recommendations will be based on the predominate vegetation appearing in these sections.

President Miller: Thank you, Mr. Webb.

I would like to point out to our audience that a considerable amount of effort has been put forth recently on the part of suppliers to let us have different types of chemicals, with combinations of letters and numbers, which make things rather confusing. This subcommittee has done a lot of work on weed and brush control, and I think its efforts certainly will be beneficial to the industry.

Chairman Crosland: Now we come to the report of Subcommittee 6, a special study on roadway formation, and its protection. At the end of this subcommittee's report we will have an address by our special speaker, which I am sure you will find very interesting.

This report will now be rendered to you by the chairman of Subcommittee 6, Mr. L. D. Shelkey, assistant to chief engineer, Bessemer & Lake Erie Railroad.

Assignment 6—Roadway: Formation and Protection. (a) Roadbed stabilization, (b) Construction and protection of roadbed across reservoir areas; specifications, was presented by Subcommittee Chairman L. D. Shelkey (Bessemer & Lake Erie).

Mr. Shelkey: This year, your committee reports on both of its assignments, with the report on Assignment (a) being submitted in two parts designated as Part 1 and Part 2. The entire report is submitted as information.

Part 1 presents pertinent tests and construction data, and some comparison of maintenance costs, on three line constructions. Two of the projects had moisture and compaction control, but no other soil engineering. The third project was built after a good survey and test program permitted incorporation of soil engineering features. The two projects required extreme maintenance, and stabilization is now being considered for the other job.

Part 2 relates the history of an 11.5-mile construction for the period 1950 to 1954. This construction had controlled compaction and moisture, with other soil engineering factors, and its chief difficulty to date has been erosion of cut slopes. This report will serve to show the value of slope erosion control.

Parts 1 and 2 were prepared under committee sponsorship by the research staff of the Engineering Division, AAR. The work is part of the cooperative investigation of the

Engineering Division and the Engineering Experiment Station of the University of Illinois, under the direction of G. M. Magee, director of engineering research, AAR, and R. B. Peck, research professor of soil mechanics of the university, and under the supervision of Rockwell Smith, research engineer roadway, AAR, who prepared Part 2 of this report.

The report on Construction and Protection of Roadbed Across Reservoir Areas is a progress report. Your committee submitted the last of three preliminary reports on this subject in 1950. Now, there is presented, for consideration and comment, a final report on the various phases of this subject, with the intention that it be proposed as Manual material in 1956.

Since the study on Construction and Protection of Roadbed Across Reservoir Areas is quite involved, I believe that we can mutually agree that our limited time does not permit any detailed discussion ot this subject here.

The Southern Railway has been using extensively and effectively several methods of roadbed stabilization. Your committee is pleased to have the privilege of presenting to this Association an illustrated address by one who has an intimate knowledge of these methods. Our speaker is Mr. J. E. Griffith, assistant chief engineer maintenance of way and structures of the Southern, and a member of Committee 14 of this Association, who will address us on the subject, Sand Pile and Sand-Filled Blast Hole Methods of Roadbed Stabilization.

Roadbed Stabilization on the Southern Railway

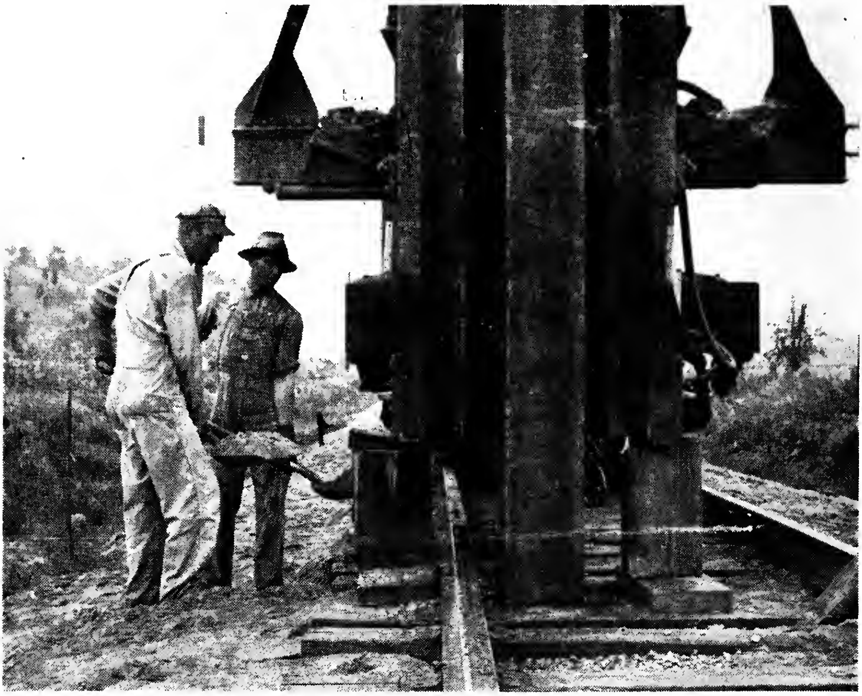
By J. E. Griffith

Assistant Chief Engineer Maintenance of Way and Structures,
Central Lines, Southern Railway System

Due to the fact that my territory covers only the Central Lines of the Southern Railway System, it behooves me to limit my remarks to actual experience within that territory. I am firmly convinced, however, that Central Lines is typical of the Southern Railway System.

The first serious attempt in stabilizing roadbed by injecting sand into impervious and unstable clay was made approximately 10 years ago. Since that time we have tried numerous methods of injecting the sand. The order in which these methods were tried are as follows.

1. We used a standard on-track pile driver with a 12 by 12-in spud which was driven into the soft clay and as near to the bottom of the soft clay pocket as practicable. This spud was then pulled and the hole filled with sand, forming a sand column.
2. The next development employed the use of a 20-ton on-track locomotive crane with leads attached to enable us to use a pile driver hammer in a method very similar to the method using the standard pile driver.
3. This development employed the method of sand blasting which in reality enabled us to create a chain of sand bulbs along the bottom of the unstabilized section and out to a point either in the side ditch or on the side fill, so that the water imponded in this area could be expelled by a principle similar to that employed in a French drain.
4. Our fourth development employed the use of a 10-ton crawler crane with a special boom and special leads which enabled us to use a pile driver hammer



Slide 1.

operated by air furnished by the required number of air compressors and piped from a convenient location for the air compressors to the actual operation of sand column driving.

5. The fifth method used the same 10-ton crawler crane and leads, but eliminated the standard pile driver hammer and the air compressors and substituted therefor a diesel pile driver hammer.

6. The sixth and last development on the Southern Railway has been the employment of a crawler tractor with an earth auger mounted thereon.

These six developments have actually resulted in only three types of roadbed stabilization.

Rockwell Smith, research engineer roadway of the Association of American Railroads, has kept in very close contact with our stabilization work and has agreed to assist me in this presentation by the use of some slides. You will notice that they are in about the same order as the steps of development which I have mentioned.

The first slide shows sand columns being formed by using the standard pile driver. We use a double line or double-block arrangement for pulling the spud. This minimizes the chance of inability to pull the spud, which would result in having to saw it off and drive it down, and also reduces the damage to the clutch operating the hoist drum on the pile line lead.

The next slide shows the use of the locomotive crane with the special leads we

Slide 2.

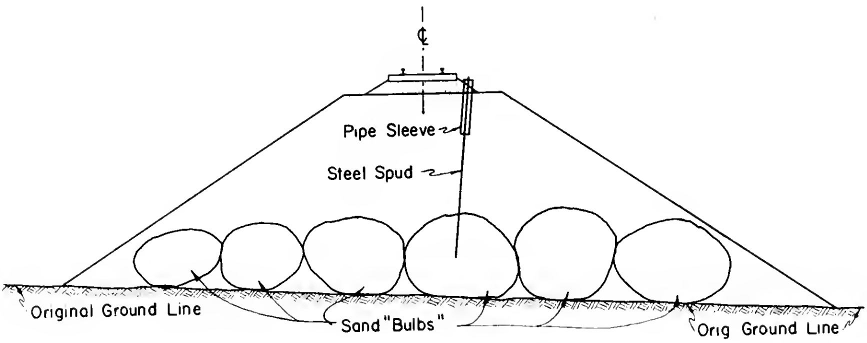
designed and constructed. The method of driving and pulling the spud is identical with that of driving and pulling it with a pile driver. You will notice, however, that the lower end of the leads have an offset in them. This offset enables us to drive a sand column adjacent to the base of the rail on either side and minimizes the blocking.

Slide 3 illustrates how the sand bulbs are utilized to form a French drain. These sand bulbs are formed by driving a steel spud and a pipe sleeve into the roadbed. The steel spud is first pulled, leaving the pipe sleeve to prevent cave-ins. A charge of dynamite is then placed in the bottom of the hole created by the spud and exploded, forming a pocket. Additional dynamite is then placed in the pocket and the pocket completely filled with dried sand. The dynamite is then exploded, thus enlarging the pocket and forcing the sand into the clay and forming a bulb-like area. This operation is continued until we are satisfied that the bulb is large enough.

By keeping records of the amount of sand put in these bulbs we are able to estimate their size closely. The process is continued until a complete line of bulbs is formed across the roadbed section. The time allotted me in this presentation does not permit giving details of the various methods, so I will have to pass on to the next one.

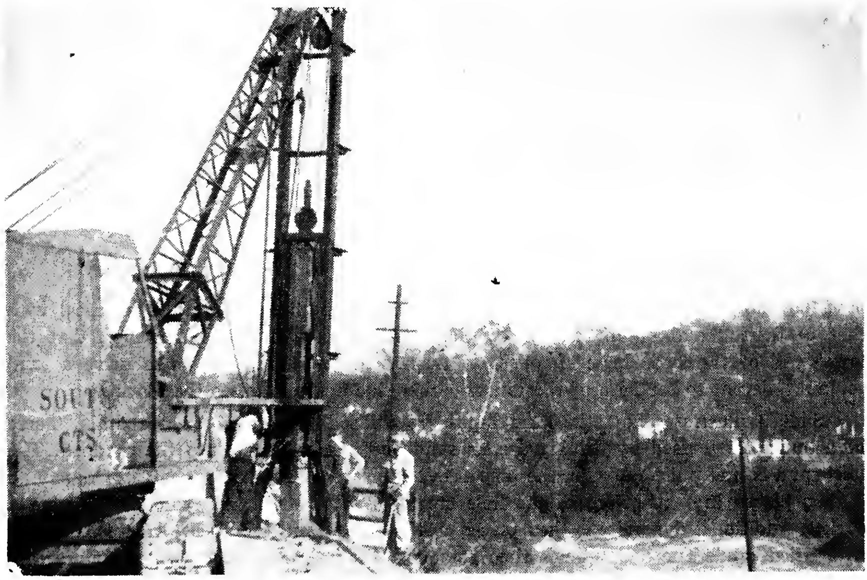
Slide 4 shows the 10-ton crawler crane with the diesel pile driver hammer. In this operation the spud is pulled at the same time the hammer is lifted.

Slide 5 shows the pattern we use with sand columns created by any of the pile driving methods. You will notice that this slide shows the pattern will give you a 20



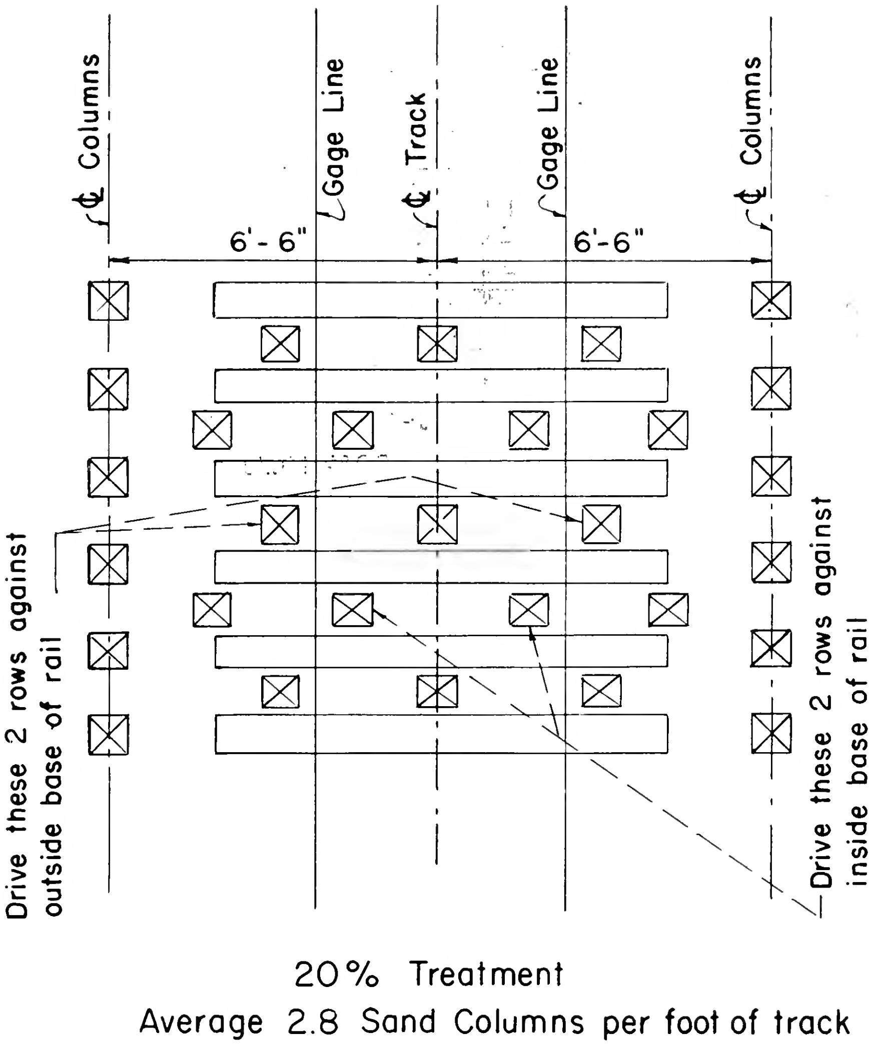
TYPICAL FILL SECTION

Slide 3.



Slide 4.

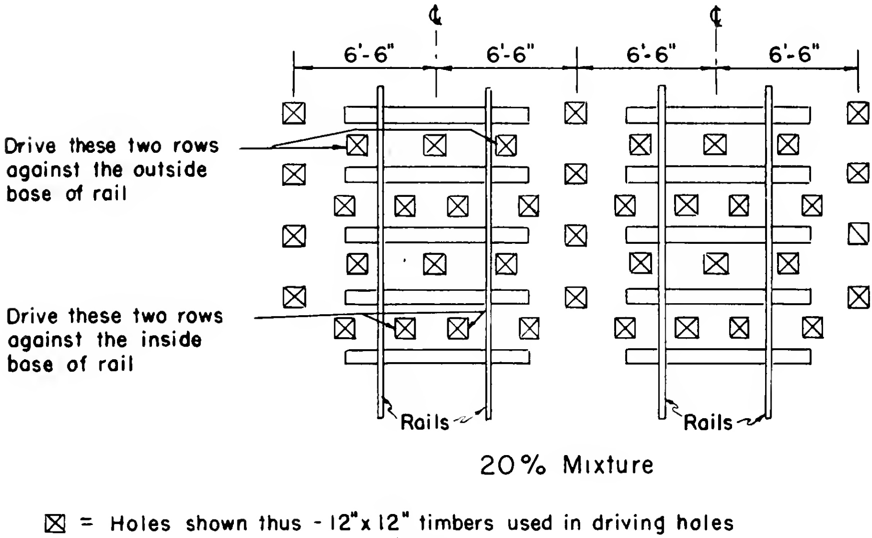
percent treatment. We have found that the 20 percent treatment actually stabilizes the roadbed and is the most economical one to use. We have also found that any treatment under 20 percent does not give good stabilization and treatments higher than 20 percent are not needed. We have cases where the roadbed was stabilized by using this treatment, the track surfaced and the soft spots completely cured. These places have been in actual use under heavy traffic, some of them for approximately 10 years, and they remain stabilized.



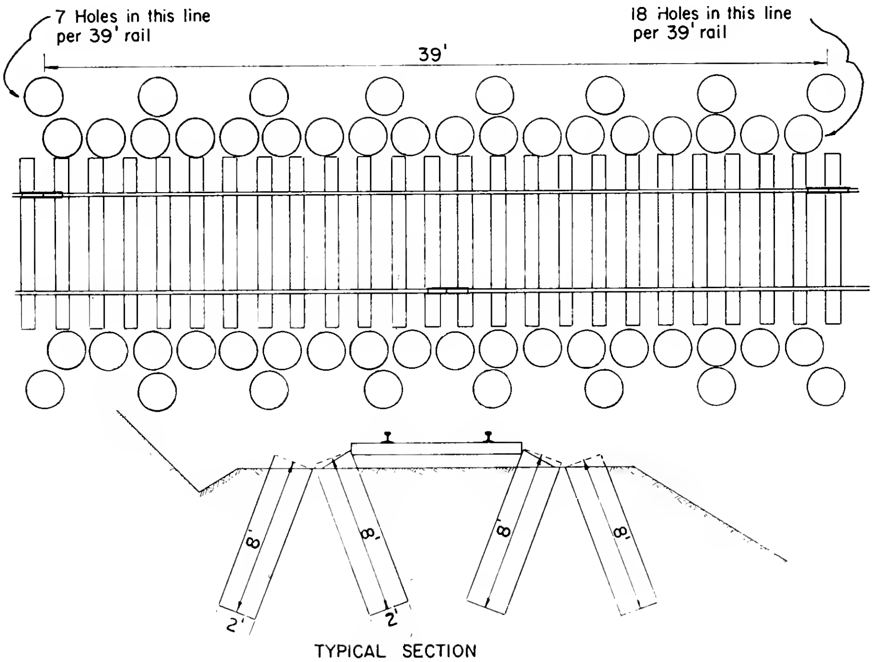
Slide 5.

Slide 6 is nothing more than a plan to show the same method employed in multiple-track territory. You will notice that the center line of sand columns between the two tracks is common to both.

Slide 7 shows the pattern used in connection with the operation employing the earth auger. The helix of this auger has a diameter of 24 in. You will notice that the line of holes drilled nearest the end of the cross ties are battered or slanted so that the center of the hole is approximately under the rail at a depth of 8 ft. This pattern requires a total of 18 holes installed at the ends of the cross ties and 7 just outside of this line



Slide 6.



Slide 7.

sloped in the opposite direction, the result being that of an inverted "V". The same operation is repeated on the opposite side of the track. My illustration shows the treatment for a 39-ft rail. This pattern gives an approximate 23 percent treatment which we have found to be satisfactory.

It is important at this point that I explain how we arrive at the percentage of treatment as I have given it. This can be done in a few words. The sand columns in the pattern have a total area which is equal to 20 percent of the total treated area. I will be most happy to explain to any of you on my own time the details of these methods.

On the Central Lines of the Southern Railway a very extensive survey was made by all division engineers during 1950. In this survey they listed their soft spots and gave a statement of how many times a week or month it was necessary to smooth them and what it cost. By consolidating and averaging these statements and by adding the increased labor costs effective between 1950 and 1954, we found that it was costing us $6.45 per track foot for smoothing only. By using the same method, we find that the sand blasting method costs $14.17 per bulb, or an average of $2.32 per foot of drain so constructed, and that the methods of forming sand columns cost an average of $2.21 per track foot so treated. You, therefore, can readily see that no one can justify the cost of continued smoothing when the stabilization work can be done for approximately one-third of the smoothing cost.

Chairman Crosland: Mr. Griffith, the committee thanks you very much for your splendid presentation. I am sorry we didn't have more time to go into more details. But we know whom to get hold of when we want to know.

Mr. President, this completes the report of Committee 1.

President Miller: Mr. Crosland, in spite of a short allotment of time, your committee has again presented a very fine group of reports. The Association always looks forward to your committee's presenting some new, interesting material.

We appreciate the leadership that you bring to your committee, which I know is stimulating and productive of its best results.

Your committee is now excused with the thanks of the Association.

Our next report will be from Committee 29—Waterproofing. The chairman of this committee is Mr. T. M. von Sprecken, assistant to the chief engineer, Southern Railway System.

Mr. von Sprecken, will you and your committee please come forward?

Discussion on Waterproofing

(For report, see pp. 477–482.)

(President G. W. Miller presiding.)

Chairman T. M. von Sprecken (Southern): Mr. President, fellow members and guests: The report of Committee 29—Waterproofing, is printed on pages 477 to 482, incl., of Bulletin 519 for December 1954. The committee was given three active assignments, and we are making a report on two of them.

The report on Assignment 1—Revision of Manual, will be given by Mr. Henry Seitz, designing engineer of bridges and buildings, Baltimore & Ohio Railroad.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman Henry Seitz (Baltimore & Ohio).

Mr. Seitz: The Manual material of this committee was completely revised in 1953, and at that time a section on Waterproofing Coatings to Prevent Concrete Deterioration was added.

After careful review by the committee, it was decided that two articles of this new specification required some clarification. The revisions as proposed are set forth in the Bulletin, and the committee, by favorable letter ballot, recommends these changes.

I, therefore, move that Part 4—Specifications for Waterproofing Coatings for Exposed Concrete Surfaces, now appearing the Manual on pages 29–4–1 to 29–4–5, incl., be reapproved with these revisions.

(The motion was regularly seconded, was put to a vote, and carried.)

President Miller: Thank you, Mr. Seitz.

Chairman von Sprecken: The report on Assignment 2—Waterproofing Materials and Their Application to Railway Structures, will be given by Mr. Nelson Handsaker, assistant bridge engineer of the Northern Pacific Railway.

Assignment 2—Waterproofing Materials and Their Application to Railway Structures, Collaborating with Committees 6, 8 and 15, was presented by Subcommittee Chairman Nelson Handsaker (Northern Pacific).

Mr. Handsaker: This report summarizes two separate investigations now in progress; one on bitumens and the other on membranes. The former, being conducted under the immediate direction of Mr. J. B. Blackburn at Purdue University, is approaching completion and we anticipate a final report next year. Our progress report states a few tentative conclusions. After presenting the final report, our committee expects to prepare improved specifications for bitumens which will be readily obtainable, effective and durable.

The membrane tests are being conducted by Mr. P. D. Miesenhelder at the AAR research laboratory. It was found necessary to redesign the testing methods formerly used, and this has consumed a considerable part of the year's effort. Next year we may have some findings on the bitumens, fabric, and number of plies for a good membrane waterproofing. In study of the bitumens, the work will be coordinated with the work at Purdue.

We are very much interested in examining membrane waterproofing which has been in service for a number of years. Membrane waterproofing is not often uncovered, and all Association members are urged to help us in this important phase of our work by notifying the committee chairman, or Mr. Magee or Mr. Miesenhelder at the AAR research laboratory, if there is to be an opportunity for such an examination.

If any of those present have any suggestions or questions, we will do our best to answer the questions and profit by your remarks, either now or in writing at any time.

Mr. President, this report is presented as information.

Chairman von Sprecken: Work has continued on Assignment 3—Waterproofing Coatings to Prevent Concrete Deterioration, Collaborating with Committees 6 and 8, but we have no report to make on this assignment at this time.

The fourth assignment, covering conservation of labor and materials, was dropped during the year, and no report is made on it.

The research work at Purdue University under the direction of Mr. J. B. Blackburn, and our committee member Prof. K. B. Woods, is progressing, and it is expected that an informative report will be made next year on the results developed up to that time.

In addition to the regular committee work, the chairman of Committee 29 represents the American Railway Engineering Association on Committee D–8 of the American Society for Testing Materials. D–8 is the committee on bituminous waterproofing and roofing materials. During the past year I attended several of the committee meetings, and I wish to report that the collaboration with that committee has been helpful to the work of Committee 29.

If the members of the Association have any questions to ask regarding the report or activities of the committees, I will be glad to try to answer them.

This meeting ends my term as chairman of this committee. It has taken a lot of time and work, but it has been pleasant work. I wish to thank each and every member of the committee for his loyal and effective support. I have had the finest cooperation and support from the members, and I feel that with their help we have been able to make definite progress.

Our vice chairman, Mr. Seitz, has been a pillar of strength to me, and the subcommittee chairmen have been especially helpful in developing our work.

I also wish to thank Mr. Howard and his staff for their help and advice.

We have been fortunate in the acquisition of several new members who will strengthen the future work of the committee.

At this time I wish to introduce Mr. E. A. Johnson, assistant engineer of bridges, Illinois Central Railroad, who is to be our new vice chairman. (Applause)

I now wish to introduce Mr. Henry Seitz, designing engineer of bridges and buildings, Baltimore & Ohio Railroad, who is being advanced from vice chairman to chairman. (Applause)

President Miller: Thank you, Mr. von Sprecken. Your committee continues to carry on important work for the Association, effectively using research where necessary, and your efforts are greatly appreciated.

On behalf of the Association I want to express, especially to you, our appreciation for the work you have done during the past three years, and particularly your work with Committee D-8, the ASTM committee, which I am sure must be beneficial to your group.

If Mr. Seitz will stand, I would like to present him with a chairman's gavel for his use in conducting the meetings of Committee 29 for the next three years. The band on this gavel reads, "Henry Seitz, Chairman Committee 29, 1955-1957." (Applause)

Mr. von Specken, your committee is excused, with the thanks of the Association.

The next committee to report is Committee 17—Wood Preservation. The chairman of this committee is Mr. A. J. Loom, general superintendent, timber preservation, Northern Pacific Railway. Mr. Loom, will you and your committee please come to the platform?

Discussion on Wood Preservation

(For report, see pp. 489-509.)

(President G. W. Miller presiding.)

Chairman A. J. Loom (Northern Pacific): This year's report of Committee 17—Wood Preservation, was included in Bulletin 519, pages 489-509, incl. Our subcommittee chairmen will report on each assignment.

Mr. C. S. Burt, assistant to vice president—purchases and stores, Illinois Central Railroad, and chairman of Subcommittee 1—Revision of Manual, will present the report and recommendations of the committee.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman C. S. Burt (Illinois Central).

Mr. Burt: This committee has continued to follow quite carefully methods and practices throughout the wood preserving industry with view to keeping our Manual chapter up to date. While we have no specific recommendations for your consideration at this time, we do call to your attention items now under study—as listed in the report.

We should like to have you review these matters, and if you have any questions or comments, the committee will be happy to have an expression of your thoughts.

In addition to the items listed in the report, this committee is also giving consideration to the development of volume correction tables for salt preservatives. It is our purpose to progress this study to early decision.

Mr. chairman, the report is offered as one of progress, and is presented as information.

President Miller: Thank you, Mr. Burt. It will be so received.

Chairman Loom: Assignment 2—Seivice Test Records of Treated Wood, will be presented by Mr. R. P. Hughes, inspector, Atchison, Topeka & Santa Fe Railway.

Assignment 2—Service Test Records of Treated Wood, was presented by Subcommittee Chairman R. P. Hughes (Santa Fe).

Mr. Hughes: Your committee submits a report of an experimental test of the preservative value of high and low-residue creosote by the Barrett Division, Allied Chemical & Dye Corporation, in connection with the School of Forestry, University of Florida, and Eppinger & Russell Company, of Jacksonville, Fla.

It also reports on inspections of tests of creosoted cross ties in a 3-deg location on the B&O Railroad.

It also reports on inspections of ties treated with straight creosote and ties treated with a mixture of 50 percent creosote and 50 percent petroleum on the Great Northern Railway.

This is a progress report, and is offered as information.

President Miller: Thank you, Mr. Hughes.

Chairman Loom: Mr. A. P. Richards is the chairman of Assignment 3 and also Assignment 6. We are very sorry Mr. Richards couldn't be here. He is having an operation on his back.

I don't know that any comment is required on his reports, other than to say that they are submitted as information. If anyone has any comments, we would like to hear them.

Assignment 4—Petroleum as Carrier or Extender of Creosote or Pentachlorophenol, will be presented by Mr. B. J. Richards, chief chemist, Southern Railway System.

Assignment 4—Petroleum as Carrier or Extender of Creosote or Pentachlorophenol, was presented by Subcommittee Chairman B. J. Richards (Southern).

Mr. Richards: This is a progress report, presented as information. No new developments have occurred in the creosote-petroleum field. However, this committee is studying the possibility of writing a specification or classification for a petroleum product suitable for blending with creosote to replace the present specification for petroleum for blending with creosote as now published in the Manual, page 17–2–3.

This concludes the report.

President Miller: Thank you, Mr. Richards. Your report will be received as information.

Chairman Loom: Assignment 5—Destruction by Termites—Methods of Prevention, will be presented by Subcommittee Chairman Mr. F. J. Fudge, timber engineer, New York Central System.

Assignment 5—Destruction by Termites—Methods of Prevention, Collaborating with Committees 6 and 7, was presented by Subcommittee Chairman F. J. Fudge (New York Central), who read the report of the committee as printed in the Bulletin.

President Miller: Thank you, Mr. Fudge.

Chairman Loom: Assignment 7—Incising Forest Products, will be presented by W. P. Arnold of the Koppers Company, subcommittee chairman.

Assignment 7—Incising Forest Products, was presented by Subcommittee Chairman W. P. Arnold (Koppers Company).

Mr. Arnold: Incised ties in the tests reported in the Bulletin continued to show a decided advantage over unincised ties, both in the seasoning stacks and in track. These tests will be continued and reported on from year to year.

The Boston & Maine Railroad has now been incising all cross ties for several years, and continues to find it advantageous.

The Seaboard Air Line recently decided to incise its cross ties, and at least two other major railroads are giving serious consideration to adopting that procedure.

President Miller: Mr. Arnold, by incising, do you mean pre-incising, before treatment, or is that incising?

Mr. Arnold: The reference is to incising green ties as they are received at the treating plant.

President Miller: Thank you.

Chairman Loom: Any further comments?

Report on Assignment 8—Effect on AREA Standards and Specifications of Any Changes in Manufacturing Processes and Specifications for Creosote, Petroleum and Other Products, will be presented by Mr. W. W. Barger, chief inspector, manager treating plants department, Atchison, Topeka & Santa Fe Railway, subcommittee chairman.

Assignment 8—Effect on AREA Standards and Specifications of any Changes in Manufacturing Processes and Specifications for Creosote, Petroleum and Other Products, was presented by Subcommittee Chairman W. W. Barger (Santa Fe).

Mr. Barger: This is a progress report. We haven't much to report, only that no new developments or changes in manufacturing processes or specifications for creosote, petroleum and other products have come to the attention of the committee during the year.

The purpose of this committee is more or less to police these specifications and keep them up to date.

President Miller: Thank you, Mr. Barger.

Chairman Loom: We have no report on Assignment 9 this year.

Assignment 10—Artificial Seasoning of Forest Products Prior to Treatment. Mr. Arnold is also chairman of this subcommittee.

Assignment 10—Artificial Seasoning of Forest Products Prior to Treatment, was presented by Subcommittee Chairman W. P. Arnold (Koppers Company).

Mr. Arnold: There is really nothing new to report, other than that which appears in the Bulletin, showing the results obtained in drying poles, lumber and gum cross ties.

President Miller: Thank you, Mr. Arnold.

Chairman Loom: The Preservatives Survey, which has been an assignment of this committee to revise at least every five or six years, was revised this year by Mr. M. F. Jaeger, superintendent, Port Reading Creosoting Plant, Reading Company, who was unable to be here at this meeting. That is printed in the Bulletin as information.

Mr. President, that concludes the report of Committee 17.

President Miller: Thank you, Mr. Loom. It is reasssuring to our Association to know that your committee is keeping an eye on all of these problems. You have again presented a series of interesting and informative reports, which enhance our knowledge with respect to wood preservation and its effectiveness under different conditions.

You are now excused, with the thanks of the Association.

Our last report today is that of Committee 6—Buildings. The chairman of this committee is Mr. O. W. Stephens, assistant to chief engineer—maintenance, Delaware & Hudson Railroad. Mr. Stephens, will you and your committee please come to the platform?

Discussion on Buildings

(For report, see pp. 425–448.)

(President G. W. Miller presiding.)

Chairman O. W. Stephens (Delaware & Hudson): Mr. President: Before proceeding with the presentation of the report of Committee 6—Buildings, we wish to express to the Association our regrets in losing a faithful member of our committee, Mr. A. G. Dorland, who retired from active service with the Elgin, Joliet and Eastern Railway in 1951, and is now being automatically dropped from the committee after serving the allotted time following retirement.

Mr. Dorland has been a member of the Association for 30 years, becoming a Life Member in 1952. During this period he was a member of Committee 23, Shops and Locomotive Terminals, from 1929 to 1937; also Committee 29, Waterproofing, from 1943 to 1945. From 1938 to 1955 he was a member of Committee 6, serving as chairman from 1948 to 1950, and during all of this time he was very active in the committee work. We surely will miss him.

The complete report of Committee 6, comprising five assignments, appears in Bulletin 518, pages 425 to 448, incl.

The first report, Revision of Manual, will be presented by Subcommittee Chairman D. E. Perrine, assistant chief engineer, Chicago & Western Indiana Railroad.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman D. E. Perrine (Chicago & Western Indiana).

Mr. Perrine: The committee recommends that Specifications for Hot Asphalt Mastic Floors, revised to include air-cooled blast furnace slag as an acceptable mineral aggregate, be reapproved with revisions.

Mr. President, I move the adoption of this recommendation.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. Perrine: The recommended changes under the heading "Excavation, Filling and Backfilling" call for reapproval of the present material and the insertion of reference to Physical Properties of Earth Materials appearing in Chapter 1 of the Manual. I move that this recommendation be approved.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. Perrine: After considerable work by a subcommittee and the entire committee, it is recommended that the section on Iron and Steel be reapproved with revision in wind load requirements, and I so move.

(The motion was regularly seconded, was put to a vote, and carried.)

President Miller: Thank you, Mr. Perrine.

Chairman Stephens: The report on Assignment 2—Specifications for Railway Buildings, will be presented by Subcommittee Chairman S. E. Kvenberg, assistant engineer, Chicago, Milwaukee, St. Paul & Pacific.

Assignment 2—Specifications for Railway Buildings, was presented by Subcommittee Chairman S. E. Kvenberg (Milwaukee Road).

Mr. Kvenberg: Subcommittee 2 has been working on the assignment covering the preparation of specifications for the application of asbestos cement products. To date we have submitted for approval a specification covering roofing shingles, and also one for siding, clapboard and shingles, and these specifications have been adopted as Manual material.

We now submit for consideration, as Manual material, a specification for 4.2-in pitch corrugated asbestos-cement siding and roofing sheets and their applications, which was published in Bulletin 518, and which is also considered of sufficient general interest to be Manual material.

Mr. President, I move that the Specification for 4.2-In Pitch Corrugated Asbestos-Cement Siding and Roofing Sheets and Their Applications, as it appears in Bulletin 518, be included in the Manual.

(The motion was regularly seconded, was put to a vote, and carried.)

Chairman Stephens: The report on Assignment 3—Shop Facilities for Diesel Locomotives, will be presented by Subcommittee Chairman J. W. Hayes, architect, Great Northern Railway.

Assignment 3—Shop Facilities for Diesel Locomotives, Collaborating with Electrical Section, AAR, Committee 12, and Fire Protection and Insurance Section, AAR, Committee 2, was presented by Subcommittee Chairman J. W. Hayes (Great Northern).

Mr. Hayes: The report on Assignment 3—Shop Facilities for Diesel Locomotives, Collaborating with Electrical Section, AAR, Committee 12, and Fire Protection and Insurance Section, AAR, Committee 2, is presented as information only, looking forward to submitting this material for adoption and inclusion in the Manual one year hence, subject to revision by solicitation from the membership.

I wonder how many of you know the number of diesel shops we have in the United States and Canada at this time. Recent surveys disclose that over 600 new and converted shops have been built since the first diesel streamliner was put into service 21 years ago this coming Armistice Day by the CB&Q Railroad, and running between Kansas City, Omaha, and Lincoln, known as the "Pioneer Zephyr".

A word about the architecture of these new buildings. Architecture is the pure art of form, reflecting a philosophy of life. Buildings are cracker boxes, shoe boxes, chicken brooder structures without ornamentation or decoration. Modern philosophers parallel modern architectural design to present-day manners without courtesy in our busy, modern business world. So much for that thought.

The more than 600 shops located on 140 railroads can be divided into four classes:

1. *Heavy repair shops,* where engine overhaul, truck and wheel work is done by the use of large cranes and drop tables. These shops average 2.5 per first class railroad.
2. *Running repair shops,* where inspection and servicing are carried out in depressed floor areas, pits, and on elevated platforms. The number of these running repair shops averages 8 per first class railroad.
3. *Electrical truck shops* for commutator work, component inspection, and cleaning average 4 per railroad, whereas major electrical overhaul points, including rewinding, average 0.8 shop per first class railroad.

4. *Overnight housing facilities*, which include one, two, three, or four-stall shelter houses for road switcher overnight or week-end storage: Minimum of repair work is done at these locations. Average is 3 per first class railroad.

The need for repairing and servicing diesel locomotives is clearly indicated because of the fact that there are 17,126 locomotives, or 23,757 diesel units, comprising more than 29,000,000 hp, in service. There have been various schools of thought as to what facilities and processes are necessary for the proper repair and servicing of the different diesel units. Although they vary considerably, they are similar in many respects.

Generally, a diesel repair shop comprises a semi-fireproof structure, either new and specifically designed for the purpose, or an existing brick and frame building converted for the purpose into which diesel units are brought for heavy repairs or periodic maintenance. This new facility will permit dismantling many old enginehouse stalls, since one 3-unit diesel has been known to replace 10 old steam locomotives.

When planning a new diesel shop it is preferable to select a longitudinal-shaped building equipped with through tracks or stub tracks, or a combination of both. The size and arrangement of a shop and the number of tracks, as well as equipment, differ on each railroad, depending to some extent on the number of diesel units in service and the policy of the particular railroad.

At the present time the trend in many instances is to consolidate the various shop and repair processes used in conjunction with the heavy repairing and servicing of diesel locomotives in one large building, and it may be expected there will be found within the diesel shop space for machine shop, electrical shop, wheel shop, engine shop, steam generator, boiler shop, tin, pipe, air brake, welding, truck, battery, filter cleaning, store room, lube oil storage, parts reconditioning and parts cleaning room, oil reclamation facilities, tool room, and office, complete with lunch, locker and toilet facilities.

Where economy in the initial investment makes it necessary to use existing frame buildings, these should be provided with reinforced concrete floors and platforms, and the superstructure should be coated with fire-retardant paint. Roofs should be protected from fires by use of metal jacks and incombustible baffles.

A new large shop must be designed to include overhead cranes, jib cranes, drop tables with release track and wheel storage tunnel, body holding devices, wheel truing machines, and other equipment to facilitate the work on diesel units. Track centers should vary between 18 and 26 ft, and release track centers should be about 23 ft on centers. Buildings should be constructed on piling where required. Footings, foundation walls, servicing and inspection pits, floors, and elevated working platforms should be constructed of reinforced concrete. Walls should be designed using either reinforced concrete, brick, cement blocks, or asbestos cement. Structural steel should be used in the walls to support roof trusses and cranes. Generous use of steel and aluminum windows should be made, along with glass blocks and corrugated glass. Track doors should be motor-operated rolling doors. The roof should be composed of steel purlins with a fireproof deck, if possible.

Fresh air heating units should be provided at a low level in the shop area to heat the building and replenish oxygen used by diesels, as well as dilute the gasses created by units operating in the shop. Overhead exhaust ducts should be installed when possible. However, when overhead cranes restrict the use of hoods, exhaust fans should be placed in roof to obtain proper air changes as required by State Industrial Codes. Proper lighting fixtures of 30 to 50 foot-candles should be installed and the painting color scheme should use pastel colors to obtain the greatest amount of light reflection.

A word may be said in connection with housing for road switchers. Metal buildings are available in a wide range of sizes, with almost complete freedom in the placement of windows and doors. If desired, buildings can be moved to new sites. These buildings are noted for their weather tightness, strength, and durability. They are fire resistant and can be erected quickly by company forces. Such buildings are available in both the United States and Canada.

The engineering departments of many railroads have contributed greatly to the good reputation of proper diesel shops throughout the country. Therefore, it is to those railroads that your committee has turned for the ideas and facts set forth in its 1955 report.

President Miller: I expect that your report has received a lot of discussion, favorable, and perhaps otherwise, from all departments of the railroads. Personally, I feel that your report is probably one of the most important that has been presented by your committee for many years. We certainly don't want to overlook any features that may be of benefit to the Association.

Mr. Hayes: I might say one word in connection with the 600 shops that I mentioned. These are both new shops and converted shops, in both Canada and the United States. Those statistics were taken from recent publications, and are correct.

President Miller: Thank you very much, Mr. Hayes.

If there is any discussion, I would certainly be willing to stay here a long time, in order that we might get the maximum information for the benefit of the Association.

Chairman Stephens: The report on Assignment 4—Wind Loading for Railway Building Structures, will be presented by the Subcommittee Chairman C. E. Defendorf, architect, New York Central, Chicago.

Assignment 4—Wind Loading for Railway Building Structures, was presented by Subcommittee Chairman C. E. Defendorf (New York Central).

Mr. Defendorf: In order to provide the Manual with more accurate and complete information for wind load considerations for the design of railway building structures, Subcommittee 4 investigated the important aspects of the problem and concluded that the recommendations made by the American Standards Association Sectional Committee A 58 were acceptable.

This subcommittee, in conjunction with the AAR, investigated the building code wind requirements of numerous cities throughout the United States, as well as the values of several national building codes, and found that there are many inconsistencies, and that most code values appear to be the result of uncritical copying of requirements found in model codes, with little or no attempt to adjust them to local conditions. Some code values are, no doubt, the result of extended study, but the basis for their determination is not clear.

While it was the desire of the committee to determine wind load values that were based upon accepted engineering principles, it became more apparent as the studies progressed that extensive tests, analyses and research would be necessary, and that the cost and time involved would be very great.

A review of the wind load recommendations of the American Standards Association, Sectional Committee A 58, indicated that the values are based upon 42 years of weather bureau data from 140 stations throughout the United States, and that there was a technical approach in determining the wind loading values.

In order to investigate the detailed analyses applied as a basis for the ASA recommendations, we met with their representatives and found that their wind loading values were based upon accepted engineering formulas and conservative assumptions where actual conditions were unknown. Such unknown conditions include the effect of wind gusts and the effect of wind on various shapes and heights of structures. As funds become available to the ASA they plan to make further tests to obtain accurate data in connection with these unknown factors.

It was concluded that the ASA wind load values are the best available since they cover the entire country and are founded on weather bureau data and sound engineering procedure.

Accordingly, the committee is recommending that the Manual be revised to include the following paragraph:

> "Wind load requirements shall be based upon the current American Standards Association recommendations for minimum wind load requirements."

President Miller: Mr. Defendorf, is this a Manual revision?

Mr. Defendorf: Yes.

President Miller: It's quite clear now. This recommendation has already been voted on under another assignment. Thank you, Mr. Defendorf.

Chairman Stephens: Our final report, on Assignment 9—Air Conditioning, will be presented by Subcommittee Chairman J. W. Gwyn.

Assignment 9—Air Conditioning, Collaborating with Electrical Section, AAR, Committee 12, was presented by Subcommittee Chairman J. W. Gwyn, assistant engineer, Missouri Pacific Lines.

Mr. Gwyn: Any information for railroad professional engineers which might discuss methods of air conditioning railroad office buildings must necessarily be very general. For a project of this size, the final design and construction supervision should be under the direction of a competent heating and ventilating specialist.

Six general methods may be followed for air conditioning railroad buildings:

1. Direct expansion mechanical refrigeration.
2. Indirect mechanical refrigeration.
3. Chilled water cooling from natural sources.
4. Evaporative cooling.
5. Steam jet vacuum cooling.
6. Adsorption cooling.

Direct expansion mechanical refrigeration is the most often found to be desirable. Direct expansion refrigeration is accomplished in one of four general ways.

A. Air distribution on a zoned basis.
B. Refrigerant distributed to expansion coils located in each zone.
C. Cooling water distributed to "Package type" air conditioners in each zone.
D. Window type air conditioners.

Indirect mechanical refrigeration is usually accomplished by circulating chilled water. Except in larger installations it is prohibitively expensive, but when the cooling load reaches 200 or 300 tons, the cost tends to become about equal to that of direct expansion refrigeration.

Cooling by chilled water from natural sources is an easy and very satisfactory method wherever nature can provide an abundant supply of cold water from springs, wells, or streams. The possibility of using naturally cold water should not be overlooked.

Evaporative cooling is the air conditioning for desert and semi-desert country. It is accomplished by passing air through a water spray or water saturated, loosely packed material. The dry air in picking up water vapor loses "sensible heat" and becomes moist air at a lower temperature.

Steam jet cooling has been infrequently installed in recent years. Its usefulness depends upon the presence of cheap and abundant steam, such as might be found around a boiler washout plant. In principle it depends upon water boiling in a vacuum at low temperature, and thus loosing its latent heat. The vacuum to so reduce this boiling point is produced by a steam jet.

Adsorption cooling operates upon the same principle as that used by a well known make of gas refrigerator. Adsorption cooling has a high initial cost and is most feasible where cheap natural gas or cheap steam occur. Its operation is accomplished without the use of moving parts and by a heat transfer process, along with the use of a lithium bromide water solution and a fractional distillation process under two different stages of vacuum.

Though my discussion may not have covered every method of air conditioning a railroad office building, it does outline a variety of ways that a given building (or buildings) might be air conditioned. Economic, esthetic and operational considerations should govern the final choice of air conditioning, but this description of various air conditioning methods may prove helpful in a preliminary selection of equipment.

This is a final report, submitted as information.

President Miller: Thank you. It will be so received.

Chairman Stephens: This concludes the report of Committee 6. I wish to thank the members of the committee for their splendid assistance during my first year as chairman.

President Miller: Thank you, Mr. Stephens. The work of your committee covers quite a broad field, and it is certainly evident from the reports that you have submitted each year that the committee is equal to the task.

This is our final report today.

I would just like to remark that our registration up to about four o'clock has exceeded any registrations we have ever had before at any of our conventions. The official figures will be out in the morning.

When this meeting recesses, we will reassemble tomorrow morning at 9 o'clock in the Grand Ballroom.

Mr. Stephens, your committee is now excused with the thanks of the Association, and this meeting is now recessed.

(The meeting recessed at 5:25 o'clock.)

Morning Session—March 17, 1955

(The meeting reconvened at 9 o'clock in the Grand Ballroom, President Miller presiding.)

President Miller: Will the meeting please come to order? We begin the closing session of our convention this morning with a report from Committee 3—Ties, of which Mr. P. D. Brentlinger, forester, Pennsylvania Railroad, is chairman.

Discussion on Ties

(For report, see pp. 471-475.)

President G. W. Miller presiding.)

Chairman Brentlinger: Before proceeding with the presentation of our formal report, I want to call attention to the recent death of one of our long-time valued members—Mr. C. D. Turley. A suitable memoir will be presented in the report of the convention Proceedings.

MEMOIR

C. D. Turley

It is with genuine regret that Committee 3, Ties, records the passing on January 27, 1955, of Charles Dalton Turley, one of its most beloved members.

Mr. Turley was born on January 28, 1886, and was graduated from Purdue University in 1911 with a Bachelor of Science degree in Civil Engineering.

He was employed by the Illinois Central Railroad as a masonry inspector in the bridge department immediately after graduation, and with the exception of one year when employed by the Caterpillar Tractor Company, worked continuously for the Illinois Central in various engineering capacities until his passing on January 27, 1955, one day before his 69th birthday.

Mr. Turley became a member of the AREA in 1934. He was a member of Committee 3—Ties, from 1936 until the time of his death, serving as chairman of the committee in 1947, 1948 and 1949. From 1947 until the time of his death, Mr. Turley was one of the AREA Committee 3 representatives on the Association of American Railroads and the National Lumber Manufacturers Association Research Project on improving the service life of cross ties. He also served on AREA Committee 1—Roadway and Ballast, from 1941 until the time of his death.

He was a member of the American Wood-Preservers' Association and The Railway Tie Association.

Mr. Turley developed a wide circle of admiring friends in his professional and railroad activities. He was held in high esteem by all those who knew him and had been associated with him. He always stood for the highest Christian ideas and was recognized by his associates as a conscientious and loyal employee of the railroad he loved and served for 42 years.

He joined the Young Men's Class, predecessor of the Howson Fellowship Bible Class, of the Woodlawn Methodist Church near the end of 1915 and was active in the class and church.

He will long be remembered for his knowledge, judgment, counsel, and friendship, which will be greatly missed during the years ahead.

P. D. Brentlinger
H. R. Duncan
Clarence S. Burt

Chairman Brentlinger: The first report of Committee 3 is on Assignment 1—Revision of Manual. Mr. L. P. Drew, assistant chief engineer, Union Pacific, will report.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman L. P. Drew (Union Pacific).

Mr. Drew: The report as published is a progress report, for information.

In reviewing Manual material, your committee found that all of the material in its chapter is up to date except for that portion of the Specifications for Devices to Control the Splitting of Wood Ties. This material should be revised and brought up to date, but your committee feels that a definite recommendation cannot be made at this time, as we wish to withhold such until the report on our Assignment 8—End Splitting of Hardwood Ties, has been completed. Therefore, the information submitted is a report of progress only.

Chairman Brentlinger: Thank you, Mr. Drew.

Our next report will be on Assignment 2—Extent of Adherence to Specifications, of which I am chairman.

Assignment 2—Extent of Adherence to Specifications, was presented by Committee Chairman P. D. Brentlinger (Pennsylvania).

Chairman Brentlinger: Members of Committee 3 continued their spring and fall inspections of stocks of ties stored by railroads for seasoning.

It is apparent that most railroads are inspecting ties on specifications patterned after the AREA Specifications for Cross and Switch Ties. Close adherence to the specifications will result in maximum tie life. Therefore, in view of the present decrease, or complete cessation of tie purchases, railroads should continue buying only properly sized ties, free of decay and strength-impairing defects, when stocks will be replenished. In the event the demand for ties increases rapidly, railroads should refrain from accepting non-standard ties in order to replenish depleted stocks quickly.

President Miller: Thank you, Mr. Brentlinger.

Chairman Brentlinger: Assignment 4—Tie Renewals and Costs per Mile of Maintained Track, will be reported on by Mr. L. W. Kistler, tie and timber agent, St. Louis–San Francisco Railway. This report was presented during one of the summer bulletins (see page 215 these Proceedings) but since the subject is important to everyone, Mr. Kistler will have some additional remarks to make at this time.

Assignment 4—Tie Renewals and Costs per Mile of Maintained Track, was presented by Subcommittee Chairman L. W. Kistler (St. Louis–San Francisco).

Mr. Kistler: Some of the more interesting phases of these annual statistics are:

In 1953, although cross tie insertions were 2.7 percent, or 808,864, less than in 1952, the unit cost per tie laid in track increased 11 cents each, or 3.38 percent. This increase in unit cost more than offset the decreased insertions, causing the average renewal cost of ties per mile of maintained track to increase $4, or to $300 per mile.

Thus, to pay for the annual cross tie insertions (arbitrarily assuming 1 cent per ton mile revenue) would require the daily movement of 2 cars of 41 tons payload each over every maintained mile of track in the country.

For a number of years the quantity of ties inserted per mile annually has been less than the five-year coverage for that year, indicating an increasing service life from ties in track. However, in 1953 these figures were the same, or 90 ties per mile, representing an average life of 33.5 years. One might conclude that this is about the average we can expect. However, your attention is called to the variations in the eight regions.

The five-year average number of ties inserted per mile for the New England and Central-Western regions were 66 and 70, respectively, whereas, for the Southwestern and Southern region these averages were 121 and 128, respectively.

The average estimated service life for the New England region is over 45 years, and for the Southern region is not quite 24 years.

It will be of interest to note in future reports if these regional differences are gradually reduced to the minimum.

President Miller: Thank you, Mr. Kistler.

Chairman Brentlinger: Assignment 6—Bituminous Coating of Ties for Protection From the Elements, will be presented by Mr. E. F. Snyder, assistant to chief engineer, Illinois Central Railroad.

Assignment 6—Bituminous Coating of Ties for Protection From the Elements, was presented by Subcommittee Chairman E. F. Snyder (Illinois Central).

Mr. Snyder: The only prior report of this subcommitee summarizes the replies received from 54 railroads in answer to a questionnaire asking what their experience has been with bituminous tie coatings, the extent of the applications, and their opinion as to benefits to be derived from this practice. This information was published in the 1953 Proceedings. The returns from the questionnaire indicated a number of railroads had established tests and believed that coating ties in track would be helpful in reducing weather checking and splitting. None of the railroads were able to evaluate the benefits of the protection because sufficient time had not elapsed to indicate their value.

Your subcommittee believes that it can best serve the Association at this time by providing a summary and index of the findings of the AREA committees and others who have reported on the subject, so this information may have a reference source under the proper committee. This is the object of the 1955 Report.

Most of the tie-coating tests have been made since 1948, and your subcommittee believes that by the end of this year the earlier coating applications will have demonstrated their value. This information, together with that from laboratory tests now in progress, will make the next report a most interesting and informative one. The present report is submitted as information.

President Miller: Are there any questions?

Mr. Snyder, I note that your report makes no reference to what economies might be derived. Do I understand that your committee is reporting only on the specification and the type of material, and that the question of what results or economies might be derived is being handled by another committee, or will you report on that, too?

Mr. Snyder: We will report on that at a later date. Most of the appilcations thus far have been experimental; in fact, all of them have. Very little out-of-face work has been done, and for that reason we have no information on the subject. However, we hope to develop this information for our next report.

President Miller: Thank you.

Chairman Brentlinger: I might add further, in connection with coatings for ties, that there has been a lot of published information along the lines Mr. Miller was asking about—the expected economies. Some thought has been expressed that the life of tie coatings might be limited to four or five years. The committee isn't entirely in accord with that at the moment, because the tests that have been reported on are rather small and the number of ties included might not reflect the true economies. Therefore, we are going to continue to progress this subject.

One specification is in draft form, and if it proves economical, and if this committee wants to recommend coatings to the Association later, we expect to present a tie coating specification.

Assignment 7—Causes Leading to the Removal of Ties; Mr. L. C. Collister, superintendent treating plant, Santa Fe Railroad, is chairman. Mr. Collister says progress and study, but no report.

Assignment 8 is another very important subject to the railroads—End Splitting of Hardwood Ties. This report will be presented by Mr. A. K. Frost, assistant to chief engineer maintenance of way, Erie Railroad.

Assignment 8—End Splitting of Hardwood Ties, was presented by Subcommittee Chairman A. K. Frost (Erie).

Mr. Frost: Considerable work has been done under similar assignments, particularly during the years 1940 to 1950, and subsequently under an assignment collaborating with Committee 5 and National Lumber Manufacturers Association.

It is intended that our present assignment will supplement the previous work, and to that end some progress has been made this past year. No detailed report is to be made at this time.

President Miller: Thank you, Mr. Frost.

Chairman Brentlinger: Mr. Magee is typical of American railroads—he's just now getting here. (Laughter)

The report on Assignment 5 of the committee is a joint research project between the AAR and the NLMA. We have had annual reports from Mr. Magee, as director of research of the Engineering Division, on this project, and he will report at this time on what has happened up to now in tie research and maximum tie life.

Progress in Tie Research Program

By G. M. Magee

Director of Engineering Research, Engineering Division, AAR

This is the seventh year of the joint research investigation between the National Lumber Manufacturers Association and the Association of American Railroads, having as its objective improving the service life of cross ties. The work has consisted principally of an endeavor to determine means of preventing checking and splitting of ties. Research to prevent or control tie plate cutting, including studies of tie plate design, tie plate fastenings and tie pads, etc., has been carried on by the Research Center staff of the AAR.

The important phase of the work in the joint investigation during the past year has been to progress further the combined seasoning and treating process in order to season green ties without splitting and checking. Since most of the checking and splitting in ties develops during the seasoning period, it can only be prevented by obtaining the ties when they are green and seasoning and treating them in some fashion to prevent its development.

The combined seasoning and treating process consists of vaporizing the water in green ties by boiling them in a mixture of creosote, creosote-coal tar, or creosote-petroleum to which has been added the necessary amount of glycol. Glycol R now being used is a comparatively inexpensive by-product resulting from the manufacture of ethylene glycol and contains approximately 82 percent diethylene glycol and 18 percent triethylene glycol. Laboratory experiments have indicated that glycol significantly reduces wood shrinkage as the water leaves the cell walls of the wood, although it does not eliminate shrinkage completely.

The process consists of placing the green ties in a creosoting cylinder and nearly filling the cylinder with a preservative solution containing glycol. The temperature is brought to 260 to 300 deg F. At this temperature the water in the wood cells is in effect boiled away until the moisture content has been reduced the desired amount. At this time boiling is discontinued and the creosote glycol solution is withdrawn from the treating cylinder, which is refilled with the glycol-free creosote solution. The ties are then pressure treated in the usual manner with the amount of preservative required, which, because of its cost, is a significant factor in the economical use of this process.

An important development was the discovery that whereas 13 percent of glycol was required in the creosote treating mixture for the initial charge which would satisfactorily season red oak ties, satisfactory seasoning could be obtained by adding a much smaller quantity of glycol to the solution to replenish the glycol content for successive charges. For example, in one series in the experimental cylinder the initial charge contained 60 lb of glycol R and 400 lb of creosote-coal tar solution. To each succeeding charge only 4 lb of glycol R was added. In a series of 16 successive charges this glycol addition was found to provide satisfactory seasoning treatment, which gave indication that the amount of glycol R required to satisfactorily season a 7-in by 9-in by 8½-ft red oak cross tie is 4 lb. It was found that an initial concentration of glycol R of 20 percent was required to satisfactorily season red gum ties. Successive charges of red gum have not yet been tried to determine whether the amount of glycol can also be substantially reduced with satisfactory results as was found possible with the red oak. Some initial runs indicated that soft maple and jack pine ties can be satisfactorily seasoned by the combined seasoning and treating process.

Another important phase of the joint research has been the evaluation of tie coatings in the exposure tests at the Teco Laboratory. A total of 34 coatings have been investigated to date. New coatings have been added to the test from time to time, the first coatings included having now been in service somewhat over 5 years. These exposure tests have indicated that tie coatings which adhere to the tie materially reduce checking and splitting. However, the best coatings included in this test appear to have a maximum fully effective life of about 5 years. Coating failures are due to weathering off of the coating and loss of plasticity resulting in breakage of the coating. Bituminous coatings with fiber or mineral fillers are more effective in minimizing checks and splits in these exposure tests than were unfilled compounds.

Rolling-load tests have been continued at the Teco Laboratory to determine whether the compressive strength of the ties has been substantially reduced by the elevated temperature required for the combined seasoning and treating process. Although sufficient rolling-load tests have not yet been completed for conclusive results, the indications in general are that the strength of the tie fibers has not been unduly affected by the temperatures required.

Some preliminary work was undertaken at the laboratory on toughening the tie plate area, making use of new resins now available. Three types of resins were tried on small wood specimens, and the results indicated that one of the three resins—Butvar B–76—sufficiently increased the toughness of red oak wood to warrant further studies.

Consideration is being given to additional service test installations of tie inserts, and for this purpose two hundred 9-in by 16-in tie inserts were made at the Teco Laboratory, using birch, hickory, hard maple and black gum. Some were made of solid wood, others were edge glued, still others were flat laminated and some were assembled with metal dowels without any adhesive. It is hoped to get these installed for service observation during 1955. During last year the installation was completed of 120 laminated ties in track on the Pennsylvania Railroad main line just east of Altoona, Pa. This is a service test installation, and several years of traffic will be required to determine much information of value on the performance of laminated ties under actual track conditions.

An inspection was made by the Teco staff of the 468 ties treated by the combined seasoning and treating process at Albuquerque and installed in the main line of the Santa Fe Railroad near Emporia, Kans. These ties have now been in track approximately 2 years and are giving very good service without showing any signs of mechanical deterioration. Many of the ties have exuded a coating forming a protective covering over the top of the tie.

The Pennsylvania Railroad is negotiating for an experimental treatment of several thousand ties by the combined seasoning and treating process in a commercial plant, and if this can be completed, as now appears possible, it will be of material assistance and develop very valuab'e information with respect to the practicality of the combined seasoning ard treating process.

President Miller: Thank you, Mr. Magee.

Chairman Brentlinger: Mr. President, this concludes the report of Committee 3, and also concludes my term as chairman of Committee 3. At this time I would like to introduce our new vice chairman for next year, Mr. L. P. Drew, assistant chief engineer of the Union Pacific Railroad. (Applause)

Succeeding me is Mr. L. C. Collister, who has served three years as vice chairman. At the conclusion of this meeting he will be the new chairman of Committee 3—Ties. (Applause)

President Miller: Thank you, Mr. Brentlinger, and your committee, for another splendid report. We appreciate the fine work which has been carried out by your committee over the past three years under your direction, and we welcome Mr. Drew as the new vice chairman and Mr. Collister as the new chairman.

If Mr. Collister will stand, I would like to present him with a chairman's gavel which will be his symbol of authority as chairman of the committee for the next three years. Mr. Collister, this gavel reads, "L. C. Collister, Chairman, Committee 3, 1955–1957."

Mr. Brentlinger, your committee is now excused, with the thanks of the Association.

The next committee to report is Committee 5—Track, of which Mr. L. L. Adams, chief engineer, Louisville & Nashville Railroad, is chairman. Unfortunately, due to the threat of a strike among the non-operating employees on the L&N, it has not been possible for Mr. Adams to attend our convention this year. In his absence the report of Committee 5 will be presented under the direction of Vice Chairman W. E. Cornell, engineer of track, New York, Chicago & St. Louis Railroad.

Discussion on Track

(For report, see pp. 733–888.)

(President W. G. Miller presiding.)

Vice Chairman W. E. Cornell (New York, Chicago & St. Louis): Your committee reports the death during the year of two of our members—Mr. R. E. Miller, chief engineer of the Frog and Switch department of the Bethlehem Steel Company, who died July 4, 1954; and Mr. W. N. Myers, division engineer, Pennsylvania Railroad, who died February 1, 1955; and one of our Members Emeritus—Mr. C. T. Jackson, retired chief engineer, Milwaukee Road, who died February 4, 1955. The memoir for Mr. Miller has been prepared and appears as a part of our advance report. The memoir for Messrs. Myers and Jackson will appear in the convention Proceedings.

MEMOIR

William Nelson Myers

William Nelson Myers, division engineer, Pennsylvania Railroad, at Pittsburgh, Pa., passed away suddenly as the result of a heart attack at Pittsburgh on February 1, 1955. He was born at Cumberland, Md., June 6, 1912, and attended Johns Hopkins University, from which he received a B.S. degree in Civil Engineering in 1933. He is survived by his wife Deborah, daughter Deborah, and two sons Willliam and Robert.

Mr. Myers entered the service of the Pennsylvania Railroad at Cleveland, Ohio on July 16, 1934, and was promoted to assistant track supervisor on April 7, 1936. After working at several locations, he was promoted to track supervisor on May 18, 1938, and to division engineer on November 16, 1948. He served as division engineer at various points on the Eastern, Central, and Western Regions.

He joined the AREA in 1948, was appointed a member of Committee 5—Track, in 1950, and was chairman of Subcommittee 1—Revision of Manual, at time of his death.

Mr. Myers will always be remembered for regular attendance at all meetings of the committee and subcommittees, and for his willing and practical help in all committee work. The Track committee will miss him as a friend and fellow worker.

M. C. Bitner
T. H. Beebe
C. H. Johnson

MEMOIR

Charles Thomas Jackson

Charles Thomas Jackson retired chief engineer of the Chicago, Mliwaukee, St. Paul & Pacific Railroad, died at his home in Columbia, Mo., February 4, 1955. He is survived by his wife, Margaret Hall Jackson, an only daughter having died as a young girl. Funeral services were held in the Methodist Chapel in Columbia, and burial was in Miami, Mo., the town where he was born on July 13, 1881.

Mr. Jackson graduated in 1903 from the University of Missouri with the degree of Bachelor of Science in Civil Engineering. On June 7 of that same year he started work with the Milwaukee Road on the rugged project of locating and constructing the Pacific Coast extension. This was the beginning of 47 consecutive years of service on the Milwaukee.

By November 1905 he had become locating engineer. He located much of what is the present main line between Harlowton and Melstone, Mont. Mountain locations which challenged his resources and ability and which he mastered in stride were 16-Mile Canyon, Smith River Canyon, Missouri River Canyon, Lewistown to Great Falls, and the Winnett Line, all in Montana. Until 1915 he was either locating new lines or constructing them. From 1915 to 1918 he worked on railroad valuation as pilot engineer and supervising survey and inventory work.

In 1918 he was made district engineer at Butte, Mont. A year later he moved to Chicago as district engineer. He was later, successively, principal assistant engineer, assistant engineer maintenance of way, assistant chief engineer, assistant chief engineer, system, and on January 1, 1950, was appointed chief engineer.

Mr. Jackson joined the American Railway Engineering Association in 1921 and became a Life Member in 1951. He served on Committee 5—Track from 1937 until his retirement in 1950 and was elected Member Emeritus in 1953. Other committees on which he served were: 1—Roadway and Ballast; 3—Ties; 7—Wood Bridges and Trestles; 14—Yards and Terminals; and 22—Economics of Railway Labor. He will always be remembered with respect and admiration for the good judgment and the clearness of the opinions and resolutions he expressed in committee work. He gave unstintingly of his time and great talents.

Mr. Jackson was an amateur golfer of quite wide renown. Although it was not until the late 30's that he took up this pastime and became a member of the Edgewater Club of Chicago, he later won several medals there, among them being the Chick Evans Amateur Trophy in 1949. His home was near the golf course, and he played winter and summer, Mrs. Jackson usually accompanying him except when the weather was too severe.

Mr. Jackson was a man of keen mentality and great will power and courage. Especially did all who knew him respect him for his fairness, his good judgment, and his outstanding ability. The Track committee will miss his counsel sorely.

Vice Chairman Cornell: Your committee had ten assignments for the year. The reports on our assignments are published in two Bulletins: Part 1 of Bulletin 521, pages 733 to 888; all of Part 2 of Bulletin 521; and Bulletin 517, page 283.

Your committee has spent considerable time and effort in progressing the work on its assignments, and in behalf of Mr. Adams, I am sure I express the feeling of all members of the committee when I say that if you care to do so, you express your appreciation of their work by comments from the floor.

There is no report on Assignment 1. During the year we had three revisions under consideration. These were more or less terms, or definitions, and we felt they were not of sufficient importance to warrant change at this time.

Assignment 2—Track Tools. This report will be given by Mr. C. E. Peterson, assistant engineer, Santa Fe, chairman.

Assignment 2—Track Tools, Collaborating with Committees 1 and 22, and with the Purchases and Stores Division, AAR, was presented by Subcommittee Chairman C. E. Peterson (Santa Fe).

Mr. Peterson: Mr. President, Members of the Association and Guests:

Your committee recommends that Track Tool Plan No. 31–54, Rail Tongs for Use with Crane, be submitted as recommended practice for adoption in the Manual. This type of rail tong is in current use on practically all railroads; therefore, it was decided to include it in the AREA track tool plans, as the former AREA rail tongs for use with cranes was deleted from the AREA track tool plans several years ago.

Mr. President, I move that the recommendation of your committee be approved for inclusion in the Manual.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. Peterson: The following is a progress report submitted as information:

Track Spike Lifter—This tool was tested on five different railroads for a period of one year and found to be satisfactory.

A plan of the tool has been prepared and will be submitted as recommended practice next year.

This tool is used to raise spikes in turnout areas, particularly at the guard rail plates, switch plates, rail brace plates, frog plates and in any location where the standard claw bar cannot easily reach the spike head.

The tool is designed to do the job safely and avoid the danger of possible injury resulting from misuse of the standard claw bar, such as striking its heel.

Claw Bar—The jaw end of this tool is not satisfactory because of its excessive hardness. An investigation was conducted, including laboratory hardness tests, which proved that a further study is required, as it may be possible to improve the design. Sixteen claw bars with various suggested changes in the jaw end are being tested on one railroad at the present time.

Track Chisel—The present AREA Track Chisel, Plan 17–53, does not specify the hardness required for this tool. As it is desirable to have the hardness requirement for all carbon steel track tools, the committee is making a study of the chemical analysis and will submit a report.

Suggested Track Gage—The present AREA Track Gage cannot be used for gaging at guarded frogs; therefore, there is need for an additional track gage. A new plan is being prepared of a gage that will be similar in design to the present AREA wood center track gage, with the exception that a guard check gage will be located on top of the gage.

Tee Socket Wrench—A tee socket wrench for removing drive spikes from switch plates, gage plates and road crossing planks has been suggested as a new AREA track tool. Such a tool is in service on a number of railroads.

Various sizes of sockets are used on this tool, depending on the type of head of the drive spike. An investigation will be made as to the possibility of standardizing on one type of drive spike head so that only one size of socket wrench will be needed. A report will be submitted in the near future.

This concludes the report on Assignment 2.

President Miller: Thank you, Mr. Peterson.

Vice Chairman Cornell: Assignment 3—Plans for Switches, Frogs, Crossings, Spring and Slip Switches, will be presented by Mr. M. J. Zeeman, engineer of track design, Santa Fe.

Assignment 3—Plans for Switches, Frogs, Crossings, Spring and Slip Switches, Collaborating with Signal Section, AAR, was presented by Subcommittee Chairman M. J. Zeeman (Santa Fe).

Mr. Zeeman: Mr. President, Mr. Chairman, Members and Guests of the Association:

As is stated in our report in Bulletin 521, your committee has reviewed all of the plans, as well as the specifications, in the Trackwork Portfolio, in order to bring it up to date. As a result, several improvements in design and in the specifications are recommended and, at the same time, we recommend to eliminate from the Portfolio those designs or specifications which are not in general use today. Also, we think it desirable that certain details common to many plans which heretofore have been shown on each plan, be removed from these plans and instead be placed on one plan for clearer presentation. This arrangement is also desirable if and when at some future time a revision becomes necessary, as then only one plan needs changing instead of many plans. A suitable note referring to the basic plan has been placed on the affected plans.

Many of the recommended revisions apply to several plans, and in order to avoid repetition in describing the revisions for individual plans, each revision item has been given a Roman numeral and the description of each item is followed by a list of the plan numbers on which this revision has been made. Our report includes eleven of these revision items, and since you have had this report before you for some time, it does not seem necessary to take time to read these items to you. Several are merely a matter of detail, but there are a few items we consider important enough to call to your attention at this time.

We wish to comment on Revision IV, Tie Layouts and Plates for Crossings. It involves the revision of one existing plan, No. 700–50, the withdrawal of one plan, No. 700 D–42, and the adoption of four new plans. These four new plans show, for the range of angles in the titles, a complete tie layout and plating, not only under the crossing proper, but including any special ties and plates required up to the point where cross ties and standard tie plates can be used. Since the recommended tie layout and plating is completely shown on the four new plans, ties and plating have been removed from all crossing plans and a note has been placed on these plans referring to the basic number of the applicable new plan. We realize that there is some difference of opinion as to what constitutes the best tie layout and plating for railroad crossings, and there may be features that some roads may consider necessary beyond what is shown in these layouts, but from the standpoint of the Association, it seems we covered this thoroughly enough so that we have a good and workable layout for general conditions.

Concerning Revision VI, Depth Hardening of Manganese Castings: A number of crossings with depth-hardened flangeway intersections installed during recent years have shown this to be a worthwhile improvement, retarding batter, flow and wear. A new paragraph, No. 410, is recommended for Appendix A to describe this feature, when specified. This specification shows the minimum Brinell hardness requirements for depth-hardened areas. While depth hardening increases the price of the crossing, a clause in the specification provides that the cost of the hardening process will be deducted from the price in cast castings fail to meet the hardness requirement.

While on this revision, I must call attention to an oversight in the description of Revision VI, on page 738. We omitted to include the two plan numbers of articulated manganese crossings. Therefore, at the end of the present description there should be added "and articulated manganese crossings Plans Nos. 782–55 and 783–55."

Revision VIII, Elimination of Girder Rail Construction: Because there is at present only a limited demand for girder rails for railroad use, we recommend the withdrawal of plans showing girder rail construction from the Portfolio. There is now only one mill in this county which rolls girder rails, and certain sections are not readily available. While girder rails were formerly used for track construction in paved streets, tee-rail construction has been found satisfactory for present day conditions. It is realized that girder rail is still used for certain purposes, but we consider this to be more of a special nature which does not warrant carrying these plans in the Trackwork Portfolio.

We submit for your approval, 4 revised plans of tongue switches from which girder rail details have been deleted, these plans now being suitable for Tee-rail construction. They are for use in paved streets. We are recommending to withdraw 10 plans, 4 of which are manganese crossings, steam over electric, 4 are for frogs and 2 plans of girder rail sections which have been carried as information.

Regarding Revision IX, Shoulder Bolts: We recommend for adoption as recommended practice, the use of shoulder bolts, instead of pipe thimbles, at heel of switch points and toe end of spring wing rail in spring rail frogs. This type of bolt has proven to be superior to thimbles and is now used by many roads.

Revision X, Bonding: Our report states that we have deleted bonding details from several plans and that we have placed a note on those plans where bonding is required, referring to current AAR Signal Section recommended practice. However, just last week, our Secretary, Mr. Howard, received a letter from Mr. Yarbrough, Chairman of Committee IV of the Signal Section, to the effect that they do not have a plan for bonding railroad crossings and believe it to be impractical to adopt one. While there is a plan for bonding turnout frogs, this seems to be of little value due to the individual railroad's preference for various types of bonds, installation methods, etc. In short, we cannot refer to AAR Signal Section recommended practice. Therefore, we wish to change the note now shown on page 739 to read—"Bonding. Per details specified by Purchaser", instead of "Per current AAR Signal Section recommended practice."

After having commented on the highlights of the revisions, we will now consider the long list of plans which have been revised and are recommended for adoption. Copies of these plans are contained in Part 2 of the Bulletin. However, you will have noted that there are other revised plans, not included in Part 2. The revisions in the other plans are of such a nature that they can be understood readily from the description given. These particular plans are marked with an asterisk in the list of plans in our report.

Mr. President, I move for adoption as recommended practice and inclusion in the AREA Portfolio of Trackwork Plans and Specifications, all of the plans beginning with Plan No. 111–55, near the bottom of page 739 and ending with Plan No. 1010–55 near the bottom of page 745 and the withdrawal of the previous issue of the plan where noted in the description. Also, the revisions in the Specifications, Appendix A–55, beginning near the bottom of page 745 and ending with paragraph 410 on page 746. Also, the withdrawal of Plan No. 700–D–42 per Revision IV, and the withdrawal of the plans per Revision VIII beginning with Plan No. 776–40 on page 746 and ending with Plan 1003–52 on page 747.

President Miller: You have heard the motion. Is there any discussion?

I would point out that this is a remarkable piece of work by this committee. A lot of plans are involved here, and I am sure that the revisions will be of great benefit to the industry.

C. J. Code (Pennsylvania): I understand that considerable use is made in some quarters of the girder rail plans, and it seems to me that it is a mistake to withdraw them, inasmuch as this is the only place, so far as I know, where any such plans are published.

I understand that when this matter was considered, reference was made to the action of the Rail committee in eliminating the specification for girder rails some years ago. That was done with the knowledge that the ASTM continued to carry a specification for girder rails which was available to anyone who wanted to use it.

I would, therefore, like to move to amend the motion on the floor to refer the matter of Revision VIII, Elimination of Girder Rail Plans, back to the committee for further consideration.

President Miller: Mr. Zeeman, would you like to comment on that?

Mr. Zeeman: Yes, Mr. President, I would.

First, I would like to know to which specific plans Mr. Code has reference. We have four plans for railroad crossings and four plans for frogs where we recommended withdrawal. Are you objecting to withdrawal of all of them, or just certain ones?

Mr. Code: All of them.

Mr. Zeeman: Now, may I continue, Mr. President?

President Miller: Proceed.

Mr. Zeeman: For the benefit of the Association, I wish to say that considerable discussion was given to this particular subject within the committee—not only the subcommittee, but the committee.

As you know, practically all of the larger roads are represented on the Track committee. Also, the leading manufacturers of trackwork material in this country are represented, as associate members. The subject came up, and was discussed thoroughly, and due to the fact that there is very limited use of girder rail as far as the railroads are concerned, and since all of the manufacturers represented stated that they had not received orders for this particular type of construction for many years, it was decided that these plans were of no further use. It is true that once in a while they do get an order for a replacement, but that's about all.

I believe Mr. Code referred to the fact that the Rail committee, some 9 years ago, recommended deletion of the specifications, as well as the girder rail designs, from the Manual, for the reason that there was very limited demand for girder rails by the railroads. Also, the information was readily available in pamphlet form by application to the American Transit Association. The convention agreed, and deleted all this material from the Manual. I think we are 9 years late with our present recommendation, because the plans which we now recommend be withdrawn are not being used.

Girder rail is not used any more by most railroads in paved streets, because Tee rail is suitable for that purpose. There are several forms in which you can use the Tee rails. You don't need girder rails.

As I said before, due to the fact that you cannot procure girder rails any time you want them (at least we were told one time when we tried to order girder rails that "We're not rolling it this year—we may roll it next year"), we feel that these plans should be withdrawn.

Furthermore, if you use Tee rails in paved streets, you don't need any of the plans as we see it, except the switch plans, and you will note that we have retained the four switch plans—1 tongue-and-mate and 3 double-tongue switches—for use in paved streets. The connections to these switches have been made so that you can use Tee rail.

If and when you would want to use girder rail, you certainly can revamp those ends back for use with girder rails.

I wonder if I have answered your question, Mr. Code?

Mr. Code: It answers it as far as I'm concerned. I understood there were some others who were going to say something about it. I wonder what happened to them? (Laughter)

President Miller: Is there any further discussion? We have a motion, but no seconder.

C. J. Geyer (Chesapeake & Ohio): Second the motion.

President Miller: Mr. Geyer has seconded the amendment.

Mr. Geyer: I mean the original motion.

President Miller: I'm speaking of the amendment at the moment. We have a motion for an amendment, but there is no seconder for that amendment.

I hear a voice out there saying he will second it—Mr. Mayo.

Is there any further discussion on the amendment?

E. E. Mayo (Southern Pacific Pipe Lines): It so happens on the Southern Pacific that there are at least three large cities in which the ordinance has never been changed, and we have never been able to get it changed—an ordinance that requires that the construction of all tracks in all streets be with girder rail. Consequently, while the Tee rail might satisfy the conditions just as well, until these ordinances can be changed, we will still have to use girder rail.

President Miller: Thank you, Mr. Mayo.

Does the chairman of the main committee wish to make any comment before we put this to a vote?

Vice Chairman Cornell: In the case Mr. Mayo mentioned, perhaps if that rail was not any longer manufactured, those cities would see their way clear to change their ordinances. I think it has been brought out, perhaps by Mr. Zeeman, that with the use of rubber tires instead of horses' shoes, we do not have so much need for girder rail construction.

I do think the committee thoroughly developed the thought that this is now an obsolete section, and that it adds nothing to the plans.

President Miller: If there is no further discussion, we will vote on the amendment. All in favor of the amendment say "aye"; contrary, "no." I believe the "noes" have it. We have no sound recorder here, but from the number of "noes," I think the "noes" have it.

We will now vote on the original motion.

(The motion was put to a vote, and carried.)

President Miller: Proceed, sir.

Mr. Zeeman: Your committee wishes to extend its appreciation to the Standardization Committee of the Manganese Track Society, whose members, as Associate Members of this committee, have rendered valuable service in the drafting of the plans and in the review of the specifications.

Your committee also presents three reports prepared by the research staff of the Engineering Division, AAR. Appendix 3(a) covers the service tests of designs of manganese steel castings in railroad crossings at McCook, Ill. This is a progress report. Appendix 3(b) covers the service tests of solid and manganese steel insert crossings supported by steel T-beams and longitudinal timbers. This also is a progress report. The third report, Appendix 3(c), Specifications for spring washers for use in special trackwork, is a final report, consisting of two parts, Part 1 being crossing frog bolt tension tests, and Part 2 being the specifications, including some revisions suggested for later consideration as recommended practice and publication in the Manual.

Mr. President, these three reports are submitted as information.

This concludes the report on Assignment 3.

President Miller: Thank you, Mr. Zeeman. They will be so received.

Is there any discussion?

Vice Chairman Cornell: Assignment 4—Prevention of Damage Resulting from Brine Drippings on Track and Structures. I shall make some comments on this report.

Assignment 4—Prevention of Damage Resulting from Brine Drippings on Track and Structures, Collaborating with Committee 15, and Mechanical Division, AAR, was presented by Vice Chairman Cornell (New York, Chicago & St. Louis).

Vice Chairman Cornell: The loss from corrosion extends over a period of time, and the insidious nature of the destruction is therefore, less dramatic than your broken rail, which might cause a derailment, but the very nature of this destruction is such that it is very difficult to estimate the amount of damage that really occurs.

Your committee has estimated that for the track and structures alone, perhaps more than $8,000,000 is lost, but the National Association of Corrosion Engineers has estimated that the loss to the railroad industry is more than $190,000,000.

I also think it would be of interest to you to know that a chemical engineer, Mr. Seymour Coburn of the AAR, has recently been made vice chairman of two important committees in the National Association of Corrosion Engineers, and in this position he is in a very good position to be made aware of all that is going on in the corrosion field. This should be of considerable value to our committee.

This report is offered as information.

President Miller: Thank you. Proceed.

Vice Chairman Cornell: Assignment 5—Design of Tie Plates, Collaborating with Committees 3 and 4. Report on this assignment will be made by Mr. M. D. Carothers, assistant chief engineer, Gulf, Mobile & Ohio Railroad.

Assignment 5—Design of Tie Plates, Collaborating with Committees 3 and 4, was presented by Subcommittee Chairman M. D. Carothers (GM&O).

(Mr. Carothers read the Introduction and Summary of the subcommittee's report).

President Miller: Thank you, Mr. Carothers. Your report will be received as information.

Vice Chairman Cornell: Our next report will be on Assignment 6—Hold-Down Fastenings for Tie Plates, Including Pads Under Plates; Their Effect on Tie Wear, Collaborating with Committee 3. Mr. J. S. Parsons, assistant chief engineer maintenance of way, Erie Railroad, will present this report.

Assignment 6—Hold-Down Fastenings for Tie Plates, Including Pads Under Plates, Their Effect on Tie Wear, Collaborating with Committee 3, was presented by J. S. Parsons (Erie) in the absence of Subcommittee Chairman Blair Blowers (Erie).

Mr. Parsons: The tests begun in 1947 in the northward main of the L&N near London and East Bernstadt, Ky., were for the purpose of developing information as to the effectiveness and economy of several types of hold-down fasteners, tie pads, and so forth, and for increasing the life of ties by minimizing plate cutting and reducing the frequency of regaging and re-adzing on curves. This test is being continued.

There were no additions or changes made to the test installation in 1954, but it is planned that two new makes of tie pads will be installed during May of this year.

A general inspection of the installation was made in May 1954, and tie pads were inspected by removal in July 1954.

Part 1 of our report includes the most important results of the visual inspection made, and because of the nearly eight years elapsed since the start of the test, more conclusive facts have been developed. Tests are being continued, and it is expected that a further careful inspection to be made in May of this year will permit our committee to present additional beneficial information in our next report.

President Miller: Thank you, Mr. Parsons. Your report will be received as information.

Vice Chairman Cornell: Assignment 7—Effect of Lubrication in Preventing Frozen Rail Joints and Retarding Corrosion of Rail and Fastenings, will be presented by Mr. R. G. Garland, assistant engineer, Santa Fe.

Assignment 7—Effect of Lubrication in Preventing Frozen Rail Joints and Retarding Corrosion of Rail and Fastenings, was presented by Subcommittee Chairman R. G. Garland (Santa Fe).

Mr. Garland: Your subcommittee reports progress on the study of the effect of lubrication in the prevention of frozen rail joints and retarding corrosion of rail and fastenings.

The tests on the Illinois Central are now four years old, and we plan to continue them. Two years ago we started tests to determine the effects of the spray method of lubrication. We will continue to respray those joints each year and develop the economies of spraying joints as compared to brush coats and packing of rail ends.

Measurements of rail gap width were repeated last summer and winter. When analyzed thes measurements show that a much more uniform rail gap is obtained when the rail ends are sprayed than is obtained from other lubricating methods. So far, there is no indication that the annual respraying of joints will reduce joint wear.

Reports from members roads using the spray method indicate that when the proper technique is followed, the annual cost of lubrication will be less than 10 cents per joint.

President Miller: Thank you, Mr. Garland.

Is there any discussion? Proceed.

Assignment 8—Field Measurement of Forces Resulting from Rail Anchorage.

Vice Chairman Cornell: There are no further developments on this subject, and the assignment is to be discontinued.

Our report on Assignment 9—Critical Review of the Subject of Speed on Curves as Affected by Present-Day Equipment, will be presented by Mr. W. R. Bjorklund, district engineer, Northern Pacific Railway.

Assignment 9—Critical Review of the Subject of Speed on Curves as Affected by Present-Day Equipment, Collaborating with the AAR Joint Committee on Relation Between Track and Equipment, was presented by Subcommittee Chairman W. R. Bjorklund (Northern Pacific).

Mr. Bjorklund: Mr. Chairman, members, and guests of the AREA:

The assignment of Subcommittee 9 relates to speed on curves as affected by present-day equipment. We have all watched track forces using level boards and noticed the apparent discrepancy in setting elevation on curves because the level board does not measure the difference in elevation at the gage line but at some high point on the tilted rails. While the magnitude of error is small, in developing a theoretical table we should use the most precise measurements available.

For the foregoing reason, your committee has been discussing a possible revision of the usual equilibrium table to utilize a base measurement, which we shall call "B", equalling the bearing distance of car wheels on rails rather than the usual coefficient "G" which is defined as gage of track, or 4 ft 8½ in. Using the bearing distance of car wheels or level board, the coefficient in the simplified formula on page 5–3–9 of the Manual will be increased 5 percent. The bearing distance as measured by the standard AREA track level board will vary from 59.3 in for high elevations in 115 RE rail to 60 in for lower elevations in 132-lb rail. Mr. Randon Ferguson of the AAR has developed from experimental data the fact that elevation should be calculated on the basis of 60 in rather than the gage distance of 56½ in.

An unbalanced elevation of 3 in has long been advocated as giving a comfortable ride. Field tests and experiments show that new modern equipment which is equipped with swing hangers, roll stabilizers, and large center bearings can negotiate curves comfortably at more than 3-in unbalanced elevation because of the reduced car body roll.

Our report is submitted as information, and further study will develop what revisions should be requested for the Manual.

President Miller: Thank you, Mr. Bjorklund.

Is there any discussion? Proceed.

Vice Chairman Cornell: Assignment 10—Methods of Heat Treatment, Including Flame Hardening of Bolted-Rail Frogs and Split Switches, Together with Methods of Repair by Welding, will be presented by Mr. S. H. Poore, assistant engineer, Chesapeake & Ohio Railway.

Assignment 10—Methods of Heat Treatment, Including Flame Hardening of Bolted-Rail Frogs and Split Switches, Together with Methods of Repair by Welding, was presented by Subcommittee Chairman S. H. Poore (Chesapeake & Ohio).

Mr. Poore: As the title of this assignment would indicate, the subcommittee is trying to determine methods of heat treatment and repair by welding. You can readily visualize that not everyone is in agreement with the proper method of heat treatment, nor, on the other hand, is everyone in agreement as to the proper method of flame hardening. At this time there is possibly some doubt as to which of those methods might survive in the production of trackwork. Then, to go further from that, after we produce the heat-treated special trackwork, there comes the question of the proper method of repair by welding.

At this time your subcommittee has a series of simulated crossings on the Milwaukee, near Mannheim, Ill. These crossings involve four different types of heat treatment and several metallurgies, and are under observation. They were installed last April, shortly after the last convention.

As of this time we can only report that they are giving good service; that there are no failures in them at this time; and that we hope to have some factual data on them to present to you at the next annual convention.

This is a progress report, offered as information. If there are no questions or discussion, this concludes the report of the subcommittee.

President Miller: Thank you, Mr. Poore.

Vice Chairman Cornell: This completes the reporting on our regular assignments.

As a special feature of our report, we have arranged for an address on the Maintenance of Railroad Crossings.

Railroad crossings occupy a unique position, being both the most expensive per-foot piece of track we have to maintain and, usually, the roughest.

Our speaker has his fair share of crossings to maintain, and, in addition to this, he has reviewed the methods of construction and maintenance used by many other railroads in an effort to determine which are the most effective and economical.

It is my pleasure at this time to introduce the chief engineer of the Terminal Railroad Association of St. Louis, Mr. V. C. Hanna.

Maintenance of Railroad Crossings at Grade

By V. C. Hanna

Chief Engineer, Terminal Railroad Association of St. Louis

During the early months of 1954 it was my privilege to investigate on a nation-wide scale the methods and practices currently being followed in connection with the maintenance of railroad crossings at grade, and to secure individual opinions on all phases of this important subject from engineering and maintenance-of-way system officers, division officials and field supervisors, representing 38 railroads throughout the United States.

While there was general agreement on many of the phases of the subject, on many others there was a wide variance in practice, methods being followed, and individual opinions. Even more interesting was the difference in results being obtained from similar installations. It is quite evident that varying conditions of subgrade, available ballast, intensity of traffic, predominant speed and other such factors, have resulted in the maintenance of each crossing being considered as an individual problem. It is doubtful if a standard of procedure will ever be agreed upon, or would even be practical or desirable. However, much improvement in our maintenance methods may be secured from a study of the experience of our contemporaries who, by their ingenuity and experiments, have developed successful and economical maintenance practices.

The information presented here is not to be considered as a recommendation and does not include consideration of the design of the crossing itself or the details of procedure being followed in connection with maintenance welding.

The subgrade should be composed of stable material and kept well drained. When this material has ceased to provide a stable foundation, generally due to lack of drainage, it has been removed to varying depths, averaging about 2 ft, and is usually replaced with clean ballast of the same type as that in use on the adjoining track. The size preferred varies from a minimum of ½ to 2 in or a mixture of the same.

At the time the subgrade is replaced, or even when ballast is renewed out of face, installation of mechanical drainage may be desirable and necessary. Perforated pipe, extending from all corners of the crossing to an open ditch, sump or dry well, and having a good fall, has been found to be quite satisfactory and economical. There is almost unanimous agreement that proper drainage is the most important single factor in the maintenance of a railroad crossing.

About one-third of the 38 reporting railroads have used reinforced concrete slabs, having an average thickness of 12 in, and the majority are satisfied with the results obtained. All agree that the slabs should be placed at least 2 ft below the ties, and mechanical drainage provided if best results are to be realized. Several installations have proved to be unsatisfactory due to uneven settling, tilting and churning, which may have been due to poor subgrade material, lack of drainage or improper design. Timber slabs are not considered to be economical or satisfactory.

The modern method of pressure grouting has been used by a number of railroads and the results have been uniformly successful. The depth to which grouting points should be driven is governed by the prevailing conditions at each crossing, but it is generally agreed that the grout should be kept a reasonable distance below the tie or timber to avoid a too rigid support of the crossing. One large western railroad has been grouting under crossings over a 10-year period and states that the effective life of the frogs has been greatly increased, with spot maintenance and out-of-face surfacing costs being materially reduced.

The ballast used is generally the same as that used in the adjoining track. The majority prefer hard, clean rock, slag or similar tough material 1½ in. in size, if available, although others favor sizes varying from ½ to not over 2 in. A minimum of 9 in of ballast under the timber is preferred and it is generally dressed from 1 to 2 in below the tops of the ties at the center of the track, and from 2 to 3 in at the ends of the ties. There is complete agreement as to the desirability of using power tampers, if available, for surfacing and even for spot maintenance. Both the air and vibratory types have been found satisfactory.

A number of railroads use different sizes of ties and timbers in several interesting arrangements, which they claim are quite satisfactory, but the large majority conform generally to the recommended standards of the American Railway Engineering Association.

There is quite general use of two or three 7 by 9-in, 7 by 10-in and 7 by 12-in treated hardwood grade and switch ties, or 8 by 10-in and 12 by 12-in timbers, bolted together and placed under each rail in the track of greater importance, considering speed and density of traffic. This arrangement has proved to be adequate and satisfactory.

There is also some use of a pad or frame, composed of 2 or 3 ties or timbers bolted together with corners secured by metal bands, placed under all 4 sides of the crossing. One large system uses all 7 by 9-in ties with uniform spacing of 20 in, and another prefers a combination of 10 by 18-in timbers and 7 by 9-in ties in small angle crossings and uses 18-in timbers entirely under crossings of angles of 35 deg to 60 deg.

Cut spikes are preferred to fasten the crossing plate to the timber, although there is some use of screw spikes. The general practice is not to pre-bore holes for cut spikes unless power tools are available. Installation of a base plate of sufficient thickness under the crossing is considered highly desirable and economical and has resulted in a considerable reduction in wear of the critical parts and saving in general maintenance.

Approximately 50 percent of the reporting railroads are using several brands of tie pads between the plate and the tie on an experimental basis. The large majority, probably 90 percent of the personnel, who reported using pads, express a rather strong personal opinion that definite economies are being realized by a reduction in wear and maintenance of the crossing itself, by increased life of the timber and lower cost of maintaining line and surface. It is recommended that more railroads make test installations of pads of different types and makes as a service to the industry, in order that economies, if any, may be more definitely determined over a period of years.

It is generally agreed that adequate anchorage is probably second only to proper drainage as the most important factor in the maintenance of a crossing, and that more anchors are usually required in all directions from the crossing than are generally used as standard practice on line of road. However, agreement ends at that point. There were almost as many different opinions as to the number of anchors to be used, and the pattern of application to be followed, as there were reporting railroads. This indicates that proper anchoring of each crossing must be determined by careful study and experience.

The extent of the expanded use of anchors on each side of the crossing varies from 100 to 400 ft, depending upon the approaching and leaving grades, alinement, intensity and direction of traffic, etc. The pattern used varies from 10 to 12 to each rail, to their use on every tie, depending largely on the personal preference of the supervising official and/or existing conditions at the individual crossing. All agree that the use of a sufficient number of anchors, whatever that may be, is necessary and economical. The anchors most generally in use, as well as those personally preferred by the majority of reporting personnel are the grip type applied to the base of the rail, although several roads use and prefer the compression clip type.

There is complete agreement that it is of utmost importance that joints within the crossing area be unusually well maintained, receive more frequent inspection than those in track, be supported by sound and well tamped timber, and bolts kept tight at all times.

Insulated joints of good design and high quality should be specified, and there is general use, almost without exception, of a canted abrasion plate on every tie supporting them. Many roads are also using tie pads under these plates on an experimental basis, others as standard practice, and there is almost unanimous opinion that their use is proving to be satisfactory and economical.

There have been rare cases where special insulated joints have been installed between crossings having different weights of rail and 15-ft centers or less, or have been fitted into tapered rails between such crossings. Any arrangement of this kind should be avoided, and it is also not desirable to use insulated joints on wing rails.

However, where these conditions do exist, or in any situation where the length of the non-track-circuited "dead" section in a crossing exceeds 35 ft, or where such "dead" section is longer than the wheel base of the short locomotive operating over this section, a special or trap circuit must be installed for proper protection, in accordance with Rule 136.55 of ICC Rules, Standards and Instructions.

A majority of the railroads prefer the use of gas welding for repairing open hearth and heat-treated crossings, and there is almost universal use of the arc process for welding manganese steel parts and solid manganese steel crossings. Maximum batter permitted before repairs are made is approximately ¼ in for al types of crossings.

Small cracks in manganese steel are not considered as serious as those in open hearth rail, but a variety of opinion exists as to the extent they should be allowed to develop before repairs are made. In manganese steel, small cracks in the bottom of the flangeway parallel to the point are not considered serious, but if the cracks are on the side wall of the points, repairs should not be too long delayed. Small cracks in the base are not considered serious, unless they are developing and travelling rather fast.

Each foreman should report any cracks to his supervisor immediately, and he, in turn, should use sound judgment as to the necessity for repairs, which will depend upon its location, size, rate of growth and effect on the casting. The issuance of definite written instructions in regard to such repairs is not considered desirable or necessary.

It is agreed that the supervisor should also determine the necessity for removing the metal flow from flangeways by power grinding before it has reached the point where chipping would occur and welding would be required, or where the flangeways have become too narrow. The thought has been widely expressed that, "we need more grinding and less welding in crossing maintenance".

With few exceptions, most railroads encounter difficulty in maintaining line and gage, particularly in open-hearth crossings and those having angles less than 45 deg. The predominant speed over a crossing has a direct relation to the accuracy of line and gage that must be maintained to insure the riding comfort of our patrons and the safe operation of trains.

Poor alinement is generally corrected by conventional methods, including driving and/or cutting certain rails after removing anchors, adjusting expansion, and lining with bars or jacks. Anchors are then replaced and it may also be necessary to rearrange the base plate and reset the "welded stops."

Gage may be corrected by grinding out flangeways, particularly in solid manganese steel, tightening or renewing bolts, inserting metal shims and/or building up existing fillers and "stops." In crossings under 45 deg struts are often placed between the obtuse angles of opposite frogs or gage plates are installed. It is desirable, economical, and usually necessary, to correct both line and gage at the same time, after which anchors may be increased if considered necessary.

Detailed inspection of all crossings is considered of great importance, the frequency required depending upon location, density of traffic, and speed over the individual crossing. The general practice being followed is to require the section foreman to make almost daily inspection and minor repairs, and the supervisors to make weekly or even more frequent inspections and authorize ordinary repairs, such as lining and gaging, surfacing, grinding and minor welding, replacement of timber and ballast, etc. The division engineer makes such inspections as he considers necessary to determine if, and when, major repairs or replacements are required and his recommendations are referred to the district or chief engineer.

The results obtained by the use of some type of ultrasonic device have been quite satisfactory on rail crossings and the rail portions of manganese steel crossings, but there is considerable doubt that such devices will always give a positive indication on manganese steel.

It is well to again emphasize that crossings subjected to heavy traffic at high speed require a higher standard of maintenance than those where low speed is normal. Accurate line and good surface are essential; stability of subgrade and proper drainage become more important; more frequent and detailed inspections are required; and the type and design of the crossings should be given careful study and consideration.

Finally, maintenance-of-way personnel from supervisors to chief engineers all agree that a high quality of maintenance of railroad crossings at grade is not only desirable and most important but is too often neglected. I believe that all of us having responsible jurisdiction over such maintenance should accept that responsibility as a personal challenge to our knowledge and ability, exercise our own ingenuity and fully utilize the experience of our contemporaries, in order to improve the economical maintenance of this vital segment of the track structure. Thus, we would provide for our patrons a smoother and safer journey over our rails, as well as render an outstanding service to our own companies and the entire railroad industry.

Vice Chairman Cornell: Thank you, Mr. Hanna, for a very fine talk.

Mr. President, this concludes the report of the Track committee. In behalf of Chairman Adams, I want to extend my thanks to the members of the committee for the excellent work they have done during the past year. Especially, I desire to thank our Associate Members in the frog and switch companies who have performed outstanding work in preparing the plans included in our report.

I also want to thank Mr. Howard and Mr. Magee and their staffs for the very valuable assistance they have given this committee throughout the year.

Mr. President, this concludes our report.

President Miller: No doubt our audience would be interested to know that the budget of our Association for the current year provides for the expenditure of about $13,500 to reprint our Trackwork plans. Of this $13,500, we will probably get back about $6,000 through sales, which indicates that your Association is also spending money on your behalf, to render a service to you.

Thank you, Mr. Cornell. Your committee has again presented a most interesting series of reports. We are particularly indebted to your Subcommittee 3 for the extensive work done in revising the plans in our Portfolio of Trackwork Plans.

We are also appreciative of the extensive assistance given in this work by representatives of the manufacturers of special trackwork.

Mr. Hanna, may I add my word of appreciation to those expressed by Vice Chairman Cornell, for your interesting address?

Mr. Cornell, your committee is now excused, with the thanks of the Association.

The final report on our program, and one which promises to be most interesting, is that of Committee 4—Rail. The chairman of this committee is Mr. C. J. Code, assistant chief engineer—engineer of tests, Pennsylvania Railroad.

Discussion on Rail

(For report, see pp. 889–986.)

(President G. W. Miller presiding.)

Chairman C. J. Code (Pennsylvania): We regret to record the passing on June 29, 1954, of Carleton Bennett Harveson, a valued member of the Rail committee. A suitable memoir appears in our report.

We also regret to report information received only yesterday, of the death of Mr. I. H. Schram, retired chief engineer of the Erie, on January 29. Mr. Schram had long been a member of the Rail committee. A suitable memoir will be presented in his honor.

MEMOIR

Irwin Herbert Schram

Irwin Herbert Schram, retired chief engineer of the Erie Railroad, died at his home in University Heights, Ohio, on February 28, 1955, after an illness of 14 months. He is survived by his wife, Mrs. Sallie McKinney Schram, and three children, Martha, Bernice, and Irwin, Jr.

Mr. Schram was born in Milwaukee, Wis., October 14, 1888, the son of Bernhard and Anna Roman Schram. Following his early education in the Chicago public schools and Armour Academy he attended Armour Institute of Technology, from which he was graduated in 1908 with the degree of B. S.

Immediately upon graduation he entered service on the Erie as a rodman. He advanced rapidly to the position of division engineer, then served for a time as trainmaster and as terminal superintendent. His further progression carried him to the position of regional engineer, then to chief engineer maintenance of way, and finally on July 1, 1946, he became chief engineer. He continued in this position until October 31, 1953 when he retired under the company's supplemental retirement plan.

As chief engineer, Mr. Schram carried the responsibility for the planning and construction of major railroad improvements, grade crossing elimination projects, new structures, etc., and during his regime, several major construction projects were undertaken, the largest of which was the Corning, N. Y. grade crossing elimination project involving a total expenditure of between $11 million and $12 million.

Mr. Schram maintained an active interest in the AREA from the time he became a member in 1916. He was a member of Committees 5—Track, from 1923 to 1948, serving as vice chairman in 1943, and as chairman from 1944 to 1946; and 4—Rail, from 1944 until his death; and a member of the Special Committee on Continuous Welded Rail from 1952 until his death. He served the Association as a Director from 1949 to 1951, and became a Life Member in 1951.

Mr. Schram was also a member of the American Society of Civil Engineers, the Roadmasters and Maintenance of Way Association of America, and the Metropolitan Maintenance of Way Club.

We feel keenly our loss in the passing of Mr. Schram, for we valued his genial personality and the high professional ability he contributed to our work.

Chairman Code: The Rail committee is reporting on 10 of its 11 assignments. In order to curtail our presentation and make time for the panel discussion which will follow, we are going to present only a brief report, omitting oral reports on several subjects. To conserve time, I would request that any discussion or questions be reserved until the end of the entire Rail committee report, at which time we will give an opportunity for such discussion.

The report on Assignment 1—Revision of Manual, will be presented by Mr. B. R. Meyers, chief engineer of the Chicago and North Western System, chairman of the subcommittee.

Assignment 1—Revision of Manual, was presented by Subcommittee Chairman B. R. Meyers (Chicago and North Western).

Mr. Meyers: Mr. Chairman, Members and Guests:

It is recommended that certain changes in the dimensions shown for the 140 RE joint bar, Fig. 7a, be changed as indicated in the bulletin so that same will conform to the information shown for other joint bars. This is basically an editorial change and I so move.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. Meyers: It is recommended that Form 402–L, which is the form for reporting annual progressive type head failures in rails, be revised so that the additional data necessary for our rail statistics can be obtained. I so move.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. Meyers: Information on rail failures in the web within joint bar limits is now obtained by letter, and it is recommended that Form 402–M be adopted for securing this information. I so move.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. Meyers: I move the adoption of Mill Practice For Rails For Butt Welding as set forth in the Bulletin.

(The motion was regularly seconded, was put to a vote, and carried.)

Mr. Meyers: This concludes the report on Assignment 1.

President Miller: Thank you, Mr. Meyers.

Chairman Code: No oral report will be presented this year on Assignment 2. I refer you to our published report for Professor Cramer's interesting report on Investigation of Failures in Control-Cooled Rail, and regret that times does not permit oral presentation of his report

I would like to ask Mr. Magee to comment briefly on Rail Failure Statistics, Assignment 3, report on which was prepared under his direction.

Rail Failure Statistics

By G. M. Magee

Director of Engineering Research, Engineering Division, AAR

I consider that the detection and analyzing of rail failures that occur in main line track is one of the most important of our Research Center projects. In effect, the entire 225,000 miles of main track in the United States constitutes a giant proving ground in which the performance of every individual rail can be followed. Thus we are able to closely check on mill performance and quickly determine whether any defects are developing indicative of poor mill practice. Also, it enables us to assess the importance of various types of rail failures so research can be directed at any type of failure which assumes sufficient importance to so justify.

The number of service transverse fissure failures showed a further decrease in 1953 of 8 percent compared to 1952. This is indeed gratifying and is indicative of the value of detector car testing and of control-cooled rail being placed in track. An extremely gratifying reduction in the number of service transverse fissures has been effected since 1943. I would like to emphasize again the importance of detector car testing in effecting still further improvements and reducing still farther the number of service TF's.

With respect to mill performance the failures during the first five years of service for all mills collectively show that the failure rate has declined steadily and that for the 1948 rollings it is the lowest so far reported. This speaks well for improvements made in mill quality, rail design, and railway maintenance practices. The 1952 rollings show a high rate at only one mill, and this was due to 26 other head failures reported by one railway. Assuming that most of the control-cooled rail laid since 1935 is still in main track, approximately 40 percent of main track is now laid with control-cooled rail. The most important types of failures from the standpoint of frequency of occurrence continue to be web failures and detailed fractures from shelling, that is, of course, in control-cooled rail.

We now have had five years of experience with the new rail sections which were strengthened in the upper web fillets and have the new bolt hole spacings. Comparison of these new sections with the old sections for a comparable five year service experience indicates almost complete control of the web failure situation, both in joints and outside of joint bar limits. Detailed fractures from shelling, however, continue to be an important problem of sufficient importance to well justify the amount of research that is being devoted in an endeavor to solve this perplexing problem.

Chairman Code: Thank you, Mr. Magee.

There will be no oral report on Assignment 4. I refer you to our published report for a summary of the progress on this assignment.

Likewise, we will present no oral report on our published report on Assignment 5.

The report on Assignment 6—Service Tests of Various Types of Joint Bars, was to have been presented by Mr. T. A. Blair, chief engineer of the Santa Fe System, and chairman of the subcommittee, but Mr. Blair is unable to be present.

You will recall that under this assignment the committee is studying the installation of 4-hole and 6-hole joints, both of 36-in length, on 115 and 132-lb rail. While these test installations have been in track for 6 years, no outstanding difference between them has shown up. Apparently the 36-in bars with 4 holes are standing up as well as those with 6 holes. A study of the graphs in the report is recommended.

There will be no oral report on Assignment 7. I commend to your reading Professor Jensen's report on rolling-load tests on joint bars, and regret we cannot allow him time for an oral report.

The report on Assignment 8—Causes of Shelly Spots and Head Checks in Rail, will be presented by the chairman of the subcommittee, Mr. L. S. Crane, engineer of tests, Southern Railway System.

Assignment 8—Causes of Shelly Spots and Head Checks in Rail: Methods for Their Prevention, was presented by Subcommittee Chairman L. S. Crane (Southern).

Mr. Crane: At the last meeting of this association your subcommittee had the pleasure of presenting to you a panorama of its research activities directed toward determining the cause of head checking, gage corner shelling and detail fractures from gage corner shelling in railroad rails.

This research work has explored the fields of metallurgy, strain gage analysis, X-ray diffraction analysis, photoelastic analysis, and statistical analysis of field service failures in a determined effort to discover the cause and possible cure for these types of rail failures.

In the early phases of the investigation we entertained hope that some relatively simple solution to the problem might be found similar to the solution found for the cause of transverse fissures in railroad rails, which have been eliminated by the controlled cooling of the rail steel during its fabrication in the rail mill.

The further we penetrated into the problem, the more apparent it became that a similar simple solution was not going to be easily found.

As each of our expert researchers applied his particular talents to the problem, the answer which he obtained tended to support the conclusions reached by previous investigators. The picture of the problem presented by each investigator showed that the failures were of the fatigue type—they resulted from multiple stressing of the rail steel at high stress levels or high ranges of stress level.

The concentration of mulitple high wheel loadings on relatively small areas of the supporting rail steel at the gage corner was creating a kneading and cold working action that exhausted the ductility of the rail steel, plastically deformed it, and led eventually to cracking.

Two possible alternatives were offered to reduce or eliminate these failures.

One of these was to strengthen the rail steel by increasing its physical properties.

To accomplish this end, heat treated rails were applied on the PRR, C&O and N&W railroads in 1949. In 1950, heat treated and alloy steel rails were applied on the NYC and alloy steel rails on the N&W.

In 1951, the GN applied heat treated rails and a test installation of high silicon rails was installed on the Rio Grande.

In 1953, the PRR applied additional high silicon rails and the PRR and N&W applied additional alloy rails.

The performance of all of these test installations has been followed by your committee.

These tests now included many hundreds of rails in 115, 132, and 133-lb RE sections, 127-lb Dudley section and 140 and 155-lb PS section.

All of the test rails have provided excellent service. They have in each installation substantially exceeded the service life obtained previously by conventional rails.

Results obtained have been so encouraging than in 1954 the GM&IR installed additional alloy rails; the GN and N&W installed additional heat treated rails and the UP, Rio Grande and Santa Fe installed additional high silicon rails.

Your committee is convinced that these additional test installations will perform well. However, economically this solution to the problem is expensive. The cost of these special types of rail steel substantially exceeds the cost of conventional rails. The use of these special types of rails will at all times be limited by the aforementioned economic factors.

The second alternative offered to solve this problem is to reduce the load imposed on the rail.

In recent years, the trend in design of cars and locomotives has been toward increasing loads imposed per inch of wheel diameter. High wheel loads and small wheel diameters will unquestionably tend to accelerate the incidence of gage corner shelling. Your committee believes that an effort should be made to limit permissible loads per inch of wheel diameter to some level which will permit our conventional rail steel to withstand without damage the service stresses imposed by these wheel loads.

Chairman Code: Thank you, Mr. Crane, for an interesting summary of the situation.

Assignment 9—Recent Developments Affecting Rail Section, will be presented by Mr. W. J. Cruse, engineer maintenance of way of the Great Northern Railway, chairman of the subcommittee.

Assignment 9 — Recent Developments Affecting Rail Section, was presented by Subcommittee Chairman W. J. Cruse (Great Northern).

Mr. Cruse: The report on this assignment is found in Bulletin 521, Part I, beginning on page 959.

Your subcommittee's principal work during the past year has been centered on the study of the effect of stress risers around a bolt hole on the fatigue life of a rail.

The failures within the joint bar limits of a rail are the most numerous of any type of failure reported in the annual rail failure statistics, which fact warranted our attention and effort in eliminating this type of failure. During the past six years considerable progress has been made in decreasing this type of failure by changes in design and limiting corrosion. It is the purpose of this study not only to evaluate the effect of these stress risers but also to suggest a practical correction of the defect in order to reduce these failures further.

Work on this assignment was carried on at the Research Center by Kurt Kannowski under the direction of G. M. Magee, employing a fatigue testing machine. The function of this machine and a description of the rail specimen with a bolt hole is described in some length in Appendix 9(a) in Bulletin 521, page 960.

To eliminate as many variables as possible, rails as rolled and inspected by the producers were used. These rails were submitted for testing by the New York Central, Louisville and Nashville, Pennsylvania, and Southern Railroads. The test specimens were selected by the railroad personnel to represent stress risers such as gouges due to improperly ground drills and burrs.

The severity of the defects varied from light to heavy drill gouges, from light to heavy burrs, as well as the location of the brand on the edge of the hole. This last condition is caused by drilling through the brand, which is the producers identification in raised letters and figures.

The segregations which occur frequently in rail steel affected the results to the extent that data of failures with segregations had to be discarded. In connection with this condition a metallurgical examination was made of the specimens which showed unexpectedly early failures and of specimens which had a long fatigue life. In every case the structure and cleanliness of the steel was normal. The failures, excepting those due to the segregations, were produced by the deformations.

A condition which shortens the fatigue life more than any other combination of defects is a fatigue failure due to a brand and a burr.

Several methods of eliminating the effects of these deformations were investigated. To eliminate the gouges, which have the least effect on the fatigue life, several specimens were reamed. They showed a slight improvement over the standard drilled holes and holes with gouges and a great improvement over holes with burrs and those drilled through the brand. Results obtained in this investigation have definitely indicated that the effect of the stress risers on the fatigue life of the rail section is very pronounced and that all these stress risers around the bolt hole are produced in the manufacturing process.

The statistical data definitely indicates that a bolt hole drilled with a dull or improperly sharpened drill through a brand reduces the fatigue life of the rail by 50 percent.

Closer control of the manufacturing process would eliminate a considerable number of detected and service failures in track.

Machining and cutting operations, such as reaming and chamfering, may not be easily adaptable to the manufacturing methods or field operations by the railroads, even though the French railroads claim great success in combatting bolt hole failures by reaming. Peening by means of a special tool appears to be by far the most practical method in that it can be adapted to use with any portable air or electric power tool. The shot peening which showed best results in extending the fatigue life requires a type of equipment which would not lend itself to adaptation to the rail production methods or to field operation by railroads. Consideration should be given to this method in salvage yard operation or in track equipment production. This report is presented as information.

Chairman Code: Thank you, Mr. Cruse.

There will be no oral report on Assignment 10—Service Performance and Economics of 78-Ft Rail, as we shall hear from Mr. Lamport, our subcommittee chairman, in the panel discussion which will follow the presentation of our report.

We have no report on Assignment 11—Rail Damage Resulting from Engine Burns.

Is there any discussion at this time on any of the items being reported on by the Rail committee? If not, that concludes the presentation of the report of Committee 4—Rail, and concludes my term as chairman.

I am most grateful to the members of Committee 4 for their wholehearted support during the past three years, and particularly to the subcommittee chairmen, who, after all, are the real work horses of the committee.

I also want to thank Mr. Magee and his staff, and Mr. Howard and his staff, for their support and cooperation.

Now I would like to present my successor as chairman of the Rail committee, Mr. B. R. Meyers, chief engineer, Chicago and North Western System, and the new vice chairman of the Rail committee, Mr. L. S. Crane, engineer of tests, Southern Railway Ssystem. (Applause)

President Miller: Mr. Code, your committee has again presented a very fine report, and we are all looking forward now to your panel discussion. Before dismissing your committee, I should like to present to your new chairman, Mr. Meyers, a gavel which will be his symbol of authority in conducting his meetings. The band on this gavel reads, "B. R. Meyers, Chairman, AREA Committee 4, 1955–1957."

Mr. Meyers: Thank you. (Applause)

President Miller: The next item is our panel discussion, and I would point out that this is a joint effort on the part of two committees, the Rail committee and the Special Committee on Continuous Welded Rail, of which Mr. L. F. Racine is tne chairman.

I will now turn the microphone over to Mr. Code, and dismiss his committee now with the thanks of the Association.

Panel Discussion on Standard Length of Rail Longer than 39 Ft, and Continuous Welded Rail

Mr. Code: Will the members of the panel please take their places at the table.

First, I want to introduce the members of our panel. In order from my immediate left they are: Mr. J. C. DeJarnette, Jr., chief engineer, Richmond, Fredericksburg & Potomac Railroad; L. T. Nuckols, chief engineer, Southern Region, Chesapeake & Ohio; E. J. Brown, chief engineer, Burlington Lines; L. F. Racine, chief engineer, Chicago, Indianapolis & Louisville Railroad and chairman of the Association's Special Committee on Continuous Welded Rail; and L. R. Lamport, chief engineer maintenance, Chicago & North Western System.

Mr. Lamport, what is the present status of 78-ft rail?

L. R. Lamport (C&NW): At the present time, Mr. Code, the interest in 78-ft rail is increasing. Prior to 1950 there were 39.4 miles of 78-ft rail on the railroads of the United States. Since 1950 203.4 miles have been laid, and in 1953 and 1954 this was stepped up considerably. Of that 203.4 miles, 62.2 miles were laid in 1953 and 107.5 miles were laid in 1954.

Some usable rail in 72 and 74-ft lengths has also been laid, but your committee on 78-ft rail has not gone into that, because it was not part of its subject.

Mr. Code: How many roads are laying 78-ft rail in any quantity?

Mr. Lamport: Four seem to be laying 78-ft rail on more than an experimental basis.

Mr. Code: In your opinion, does the decision handed down to us by the AAR Board of Directors following its conference with the steel company representatives put an end to consideration of 78-ft rail?

Mr. Lamport: No, I think not. It will possibly slow it down, because it will mean that the railroads will have to weld to secure 78-ft rail. However, I feel that if more roads would go into the economics of welding, they would find that they can produce 78-ft rails as cheaply as they could get them from the steel companies, at least in the earlier stages.

Mr. Code: Mr. Brown, I understand you have laid a considerable mileage of 78-ft rail. What factors were considered in your decision to go ahead with such rail on a large scale?

E. J. Brown (Burlington Lines): Joint maintenance is responsible for 16 to 20 percent of all track maintenance. By using 78-ft rail, with only one weld, we reduce the number of joints by 50 percent. If we went to 195-ft rail with 4 welds, the additional reduction would only be 30 percent. The 78-ft rail presents no problem insofar as laying is concerned. In fact, it lays a little faster than the 39-ft. Furthermore, very little problem is introduced in the unloading of it.

In our adoption of 78-ft rail we considered the likelihood of damage to rail through derailments. Rails of such length can readily be replaced, whereas damage to long continuous stretches of rail might necessitate taking out the whole string.

We also considered the present of shelly fractures. Where such develop in continuous welded rail, it would be necessary to take out the entire rail or to cut it where desired.

On our property we have to supply—from our new rail territory—repair rails for about half the mileage of our railroad on secondary lines. In providing that rail, we feel that the 78-ft rail could be handled much easier than longer stretches. At the present time we have 140 miles of 78-ft rail in track.

Mr. Code: Have you obtained any 78-ft rail from the mills?

Mr. Brown: No.

MR. CODE: It has all been made by welding?

MR. BROWN: Yes.

MR. CODE: Is the 78-ft rail made by welding as satisfactory in all respects as 78-ft rail delivered as such from the mill?

MR. BROWN: We think so.

MR. CODE: How about alinement at the weld?

MR. BROWN: We have had a little difficulty with alinement at the welds, but this has been corrected through improvements in our methods.

MR. CODE: How about the question of base reinforcement interfering with tie spacing?

MR. BROWN: We have had some trouble with this, but here again, I think that will be solved. It has been solved by some railroads, by eliminating the bulge at the weld.

MR. CODE: Mr. Lamport, what is the status of the specifications for 78-ft rail?

MR. LAMPORT: The subcommittee submitted a specification to the Rail committee, and that, in turn was handled through the Joint Contact Committee with the steel company representatives, who have taken it in hand for study and such revision as they may feel is necessary to fit mill practices.

MR. CODE: That refers, of course, only to mill-manufactured 78-ft rail.

MR. LAMPORT: That is correct.

MR. CODE: Mr. Lamport, in what kind of territory would you first consider the laying of 78-ft rail?

MR. LAMPORT: I would first consider laying it in troublesome stretches, such as was done two years ago, I believe, by the Louisiana & Arkansas, where they laid 78-ft rail over a swamp 10 miles in length. Through the 78-ft rail and reballasting, they have substantially increased their train speeds over that swamp, and will no doubt decrease their maintenance costs along with it.

MR. CODE: You would pick out the locations then where joint maintenance is the most serious problem.

MR. LAMPORT: Yes, if I were going to limit it to a portion of the laying.

MR. CODE: Mr. Nuckols, you have indicated that you are not sold 100 percent on 78-ft rail. What are some of your objections and misgivings?

L. T. NUCKOLS (C&O): Surely, the elimination of joints is desirable, Mr. Moderator, but it seems to me there are several things that we should consider before we go into this wholeheartedly.

For instance, if the rail comes from the mill in 78-ft lengths, we would be faced with the difficulty, in my situation, of proper drop-end cars for hauling the rail, and the need for the larger cranes—which we do not have at this time—to handle them. Those things have to be overcome before we can go to the 78-ft rail.

MR. CODE: Is there any objection to laying 78-ft rail in mountain territory?

MR. NUCKOLS: In my opinion, yes.

MR. CODE: Due to the necessity for transposition, due to curve wear?

MR. NUCKOLS: Unfortunately, we still have individual rail failures on our railroad. Maybe some do not. We find it is a whole lot more desirable to change out a 39-ft rail than it would be to change out a 78-ft rail. We don't have sufficient forces to handle 78-ft rail, whereas we can handle 39-ft rail.

MR. CODE: Mr. Lamport, would care to comment on the question of changing out a defective 78-ft rail?

MR. LAMPORT: I don't believe it presents very much of a problem. Of course, it takes a little different handling than in the case of 39-ft rail, but our failures in 78-ft rail have not created any problems to speak of. You can change out a 78-ft rail with two 39's if you don't have the 78-ft rail on hand, but we keep a stock of 78-ft rails.

Mr. Code: How does the cost of material per mile compare for 78-ft rail made by welding, and 39-ft rail, assuming $10 per ton for the cost of welding?

Mr. Lamport: I don't have the answer on that basis. I have computed that a joint is worth $9.65, including the bond, and a modest figure for a weld is $12, which I think can be reduced to somewhere in the neghborhood of $10. On that basis the welded rail, that is, the 78-ft rail, would cost $297 a mile more than the jointed rail, assuming that the anchorage is the same, which is true with most 78-ft rail being laid.

Mr. Code: Mr. Brown, what is your cost of welding 78-ft rails?

Mr. Brown: Our average cost has been about $12.

Mr. Code: About $12 per weld?

Mr. Brown: And as Mr. Lamport has said, that can be reduced. We find that to reduce the cost of welding, it is advantageous to check and double-check the welding crew.

Mr. Code: Mr. Lamport, we've been talking about 78-ft rail, whereas I believe our topic was standard lengths of rail longer than 39 ft. What were some factors considered by the Rail committee in deciding to concentrate its efforts on the 78-ft length?

Mr. Lamport: Primarily the handling and shipping. The 78-ft rail can be handled better than any longer length, and it was deemed advisable not to go below that.

We can handle 78-ft rail either on two flat cars or on 65-ft drop-end gondolas with an idler. Furthermore, it can be worked in with 39-ft rail, particularly around switches, where you might have some 39's, and a 19½-ft joint stagger is better than some other length.

Mr. Code: The possibility of replacing one 78-ft with two 39's in the event of failure didn't appear to be an important factor?

Mr. Lamport: I don't think it was brought up at the time the questionnaire went out and the answers came in from the various railroads.

Mr. Code: Mr. Brown, what type of crane equipment is needed to handle 78-ft rail, that is, in laying and in unloading?

Mr. Brown: The same equipment can be used in either case. There is a crane with a 55-ft boom, with spreader bar, with which this can be accomplished.

Mr. Code: Other than the crane, what special rail-laying equipment, if any, is necessary?

Mr. Brown: None, if you have a crane with the required capacity.

Mr. Code: Mr. Lamport has covered the method of loading as to cars. Mr. Nuckols, do you anticipate any difficulty in handling 78-ft rail from the point of manufacture to the point where it is to be laid?

Mr. Nuckols: I think we would be faced with the difficulty I mentioned before. There is the matter of equipment and the handling of the rails. Mr. Brown seems to have overcome these pretty well; it sounds reasonable. We have had no experience with it up to this point.

Mr. Code: Mr. Lamport, what are the maintenance economies of 78-ft rail versus 39-ft rail?

Mr. Lamport: On the basis of information we have at present, the 78-ft rail will cost from $300 to $400 per mile less than the 39-ft rail for maintenance.

Mr. Code: Mr. Brown, what is your view as to the total first cost per mile of 78-ft rail versus 39-ft rail?

Mr. Brown: I don't have figures available for that, Mr. Code.

Mr. Code: How much expansion allowance should be made in laying 78-ft rail, Mr. Brown?

Mr. Brown: We use the same expansion as we do with the conventional 39-ft rail.

Mr. Code: The same. You make no additional allowance for additional length?

Mr. Brown: That is right.

Mr. Code: Mr. Lamport, in your experience, does 78-ft rail have a tendency to develop its own expansion—that is, to push itself out in warm weather, so that the total expansion finally approximates the theoretical requirement?

Mr. Lamport: With proper anchorage, I see no reason why 78-ft rail should ever reach the theoretical. It has not done so with us. We started out with 1½ times the expansion of the 39, then we laid it with 1¼, and found that was too much. Now, as Mr. Brown has stated, we lay it with the same allowance for expansion as we do the 39.

Mr. Code: And you find you are able to hold it?

Mr. Lamport: That is correct.

Mr. Code: Mr. Brown, how should 78-ft rail be anchored?

Mr. Brown: We anchor our 78-ft the same as we do the conventional 39-ft rail.

Mr. Code: You don't find any additional anchors are necessary?

Mr. Brown: No, sir.

Mr. Code: Is it essential, Mr. Brown, that 78-foot rail be end-hardened?

Mr. Brown: We end-harden it, yes.

Mr. Code: You think that is highly desirable?

Mr. Brown: Yes.

Mr. Code: Mr. Brown, can 78-ft rail be worked—that is, raised, tied and ballasted—in hot weather, or weather that is warmer than the temperature at which it was laid?

Mr. Brown: I think that is one of the definite advantages of the 78-ft rail versus the longer rail.

Mr. Code: In the event of a rail failure, how do you handle it, Mr. Brown? Do you replace with 78-ft or with two 39's?

Mr. Brown: Well, out of 140 miles, we haven't had a failure yet, so that hasn't confronted us, but I think we would put in two 39's, at least temporarily, until we could supply a 78-ft rail. We don't carry the 78-ft, as such, on the individual sections for emergencies.

I might say that in laying our 78-ft rail we break the joints 19 ft 6 in, so that if we do drop a 39-ft length in we always have broken joints.

Mr. Code: You still have proper stagger.

Mr. Brown: That is right.

Mr. Code: Gentlemen, that concludes the time that we had set aside for direct questioning of the panel by the moderator. We have 10 min in which we can entertain some questions from the floor.

Question: Does that cost per joint for welding include the additional handling necessary to take the 39-ft rail to the welding spot and then out on the line.

Mr. Lamport: It does. That is the complete cost, from the time the rail comes into the welding setup until it leaves on cars again.

E. S. Birkenwald (Southern): I wonder if Mr. Brown can clear up this point. He said that he uses as many rail anchors for the 78-ft rail as he does for the 39-ft rail. Does he mean that the number he uses for the 39 applies to the 78, or is it double the 39?

Mr. Brown: Double the 39-ft rail.

Mr. Code: The same number of anchors per mile?

Mr. Brown: That is right.

Question: I'd like to know what weight rail they are using.

Mr. Lamport: I believe Mr. Brown's rail is both 112-lb TR section and 129-lb TR section. We are using 115-lb. The other large users are using 115-lb.

On any weight of rail above 115, I see no reason why they shouldn't weld it as well as the 115 and 129.

Question: Mr. Lamport, are you comparing your cost against a four-hole joint?

Mr. Lamport: No, that was based on a six-hole joint.

L. V. Johnson (Soo Line): Welding the 78-ft rail shortens the rail. Mr. Brown has never changed one out, but maybe Mr. Lamport can say how the two 39-ft lengths fit in the shorter 78-ft length.

Mr. Lamport: I can't answer that for you, because we haven't had any experience with it either, but I would say that the difference there is about ¾ in, and I'm sure you have bumped rails to pick up three-quarters of an inch.

W. D. Almy (CRRofNJ): We use 140-lb rail on our railroad. We're having considerable trouble with the upset on the base. As I understand it, with 100-lb you have practically no trouble with the upset. You can grind it off, but as you get up to the 140-lb section, your base drops down so that if you grind it off you're going to grind off some of your original metal. I am very much interested to find out how you folks are overcoming this upset problem.

Mr. Code: Mr. Lamport, would you care to comment on that?

Mr. Lamport: We have not ground off any of the upset on the underside of the base as yet, so I cannot answer that.

Mr. Code: Have you had any experience with that, Mr. Brown?

Mr. Brown: No, sir, we haven't. Of course, it's necessary either to split your tie plate or cut a hole in the tie plate to accommodate this bulge, or to space your ties.

Mr. Code: Possibly Mr. Racine could comment on that, from the information gathered by the Committee on Continuous Welded Rail? Mr. Racine.

L. F. Racine (CI&L): We did have some discussion about that in the committee, and Mr. Magee, director of engineering research, AAR, went into that quite thoroughly. He reported verbally on November 9, 1954, that he had completed rolling-load tests on six specimens of gas pressure-welded joints, three having and three not having the upset metal removed from the rail base.

With the assistance of graphs, Mr. Magee explained how two specimens were tested under a wheel load of 65,000 lb. The specimen with the metal bulge failed after 115,000 cycles, whereas the specimen with the bulge ground off withstood 600,000 cycles before failure.

He continued with this test, down to a 55,000-lb wheel load, and the specimen having the bulge failed at about 650,000 cycles, whereas the specimen with the bulge removed did not fail up to 2,000,000 cycles, when the test was stopped.

It indicates that the fatigue strength here increases, but there was some question in his mind about the drop test that was made. The two specimens were sent to the steel mills, and I was surprised to hear that the specimen having the upset metal removed failed on the first blow, whereas the specimen having the bulge did not fail until the fifth blow.

I think he has requested that six additional specimens be sent to the mill for check on this drop test. He doesn't want to put his reliance on the one test.

So it would seem that you are perfectly safe in removing the bulge, or the upset weld, at the base.

Mr. Code: Do you know the weight of these rails.

Mr. Racine: They were 115 and 132-lb, as I recall.

Mr. Code: Mr. Almy, I think you called attention to a very important point, and one that we probably don't have the final answer on, which requires some further development. I believe your railroad has done quite a lot in the way of working with long length rails; would you care to tell us a little bit about your experience with it?

Mr. Almy: We have about 105 miles of welded rail, ie., 78-ft rail. In addition, we have also cropped our rails coming out of track, and have put out 70-ft second-hand welded rails which have been used very successfully in our main track; sometimes we have subsequently cropped that coming out of the main track and used it in yards.

This problem of the upset, of course, is one with which we are vitally concerned. Formerly, we cut off the tie plates, or portions of them. Then we started moving our ties. However, you can't do this very well on bridges.

As I mentioned a few minutes ago, our biggest problem is grinding off the upset on 140-lb rail. When you weld it, you not only have an upset on the base of the rail, but the base seems to drop slightly, so that if you were to grind it off, you would be grinding off some of your original section.

I understand from the Oxweld people that they, too, are experimenting with this. They seem to think that proper methods of heating and proper placing of the flame will eventually overcome this problem.

On our railroad we stagger our joints 19½ ft. Also, we probably put our anchors in a little differently from other roads. We put them in at the center of the rail, 16 of them to a rail. Consequently, we do not have our anchors opposite each other. So far, this has proved very satisfactory. I haven't been able to find any ties that were sluing on this account.

So far as the space between rail ends is concerned, we are still using 1½ times that used for a 39-ft rail.

Mr. Code: Thank you very much, Mr. Almy.

That about uses up our time for the 78-ft rail problem, so we will commence the panel discussion on continuous welded rail.

Mr. Racine, what is the present status of continuous welded rail? How much has been laid in recent year, and how much is programmed for this year?

Mr. Racine: The total mileage of continuous welded rail, as near as can be ascertained, from 1933 to 1951, incl., amounted to 247.5 miles, of which 208.6 miles was in open track and 38.9 miles in tunnels. This mileage increased appreciably through the years 1952–1954.

The rail sections involved vary from 90-lb to 140-lb, with the 131 to 140-lb accounting for approximately 75 percent of the total mileage.

In 1952, on 23 railroads throughout the United States, a total of 33,783 welds were made, of which approximately 40 miles were of continuous welded rail. The balance was in double and triple lengths in various locations.

In 1953 a total of 48,987 welds were made on 17 railroads throughout the United States, with approximately 80 miles of continuous welded rail, and the balance on double and triple-length rails used on miscellaneous projects.

The proposed rail welding for 1955 is problematical. We have secured some information from the Oxweld people, and from the Matisa Corporation, and it looks as though there will be a possible total of 235 miles of continuous welded rail using the Oxweld method, laid on 15 railroads throughout the United States in 1955, and approximately 90 miles using the Matisa flash butt weld, or, at the end of 1955, there should be approximately 750 miles of continuous welded rail in service.

Mr. Code: What methods of welding have gained general acceptance?

Mr. Racine: The oxyacetylene pressure weld accounts for practically all continuous welded rail. The Matisa Corporation is now entering the field with the flash butt weld, and this competition will be welcomed. There has been some talk about the Sperry Corporation entering the field, but there is nothing definite about that at the present time.

Mr. Code: What is the view of your committee as to the relative economy of continuous welded rail on a long-range basis?

Mr. Racine: The committee seems to think there is considerable saving through the use of continuous welded rail; that there should be a saving of probably $650 a mile in joint maintenance.

Mr. Code: What is the present thinking as to the best temperature for laying continuous welded rail?

Mr. Racine: There is some question about the temperature at which the rail should be laid. It is recommended, however, that wherever practicable the rail be laid during the summer season, preferably at temperatures ranging between 70 and 90 deg F.

In locations in the extreme South and in the extreme North, these limits should probably be slightly increased or decreased, respectively. Continuous rails have been installed at temperatures as low as 28 deg F and as high as 130 deg.

It is recommended that any out-of-face surfacing, lining, tie installation, etc., be done at temperatures comparable to those at which the continuous welded rail was laid. While we have no definite information about this, you shouldn't attempt to do any of this work at temperatures 15 deg above that at which the rail was laid, and the work should preferably be at temperatures lower than that at which the rail was laid.

Mr. Code: Mr. DeJarnette, what do you find to be good practice with regard to working continuous welded rail in warm weather?

J. C. DeJarnette, Jr. (RF&P): The nearer the original laying temperature, the better, but if you don't take too much liberty with it, and disturb only a small piece of track at a time, you can work at considerably higher and lower temperatures.

Mr. Code: On a long-range job where rail must be laid at widely varying temperatures, should anchoring and end expansion be adjusted later?

Mr. DeJarnette: Yes.

Mr. Code: You have had some experience with that?

Mr. DeJarnette: Yes.

Mr. Code: In other words, you start out on a long program of laying continuous welded rail and you probably have to take the temperatures the way they come.

Mr. DeJarnette: That is right. When you make your plans and divert your traffic, you have to carry your plans through.

Mr. Code: Have you had any difficulty with alinement at the welds in continuous welded rail?

Mr. DeJarnette: We had some difficulty with the first welds that we made, but we have improved our roller line beyond the normalizer, and have eliminated most of the difficulty with the joints.

Mr. Code: You are getting good alinement now?

Mr. DeJarnette: Yes.

Mr. Code: Mr. Racine, how should closure welds be made?

Mr. Racine: Closure welds are made according to the desires of the individual railroad. Some prefer the field weld rather than the conventional joint closure, and both have been satisfactory.

I understand that the Santa Fe is now using the conventional joint instead of the field weld.

Mr. Code: Mr. DeJarnette, how do you feel about closure welds?

Mr. DeJarnette: We have eliminated the closure welds. We lay most of our rails in strings of 39-ft rails welded together, and use the conventional joint in the field.

Mr. Code: Mr. Racine, has there been any disposition in this country to use a type of weld which may be made in track, except for closure welds?

Mr. Racine: The committee has not learned of any attempts in this country to make welds in track other than the closure weld. Some such welds may be made in foreign countries, but no definite information is available.

It is the consensus that the welding of continuous welded rail should be done at a plant site near the location where the laying is to be done. However, in the past few years it has been the practice to ship continuous welded rail in long lengths for considerable distances. For instance, the Northern Pacific shipped rail welded at Big Timber, Mont., to the Pacific Coast, with no special problem.

Mr. Code: What type of weld is generaly considered best for closure welds?

Mr. Racine: The oxyacetylene weld is the only weld that I know anything about.

Mr. Code: Mr. DeJarnette, do you find it necessary to make any special provision with respect to the joints at the ends of welded stretches—insulated joints, for instance?

Mr. DeJarnette: We put in short rails each side of the insulated joints, and at the ends of the strings we extend our anchoring pattern six rail lengths on the conventional rail.

Mr. Code: This matter of using short rails adjacent to the insulated joint—was that the result of your experience with some difficulty?

Mr. DeJarnette: Yes. We had difficulty with the thimbles in the insulated joints; the bolts wore through the thimbles.

Mr. Code: In other words, the additional expansion provided by a couple of short rails takes care of that?

Mr. DeJarnette: Yes.

Mr. Code: How should continuous welded rail be anchored, Mr. DeJarnette?

Mr. DeJarnette: We have accepted the recommendation of the Committee on Continuous Welded Rail for anchoring. Starting at the end of the string, we anchor six rail lengths, boxing every tie. Between the end anchoring we box anchor every other tie. We do this so that in case there is a break the rail won't pull apart.

Mr. Code: That is to avoid difficulty where a break occurs in the center of a stretch?

Mr. DeJarnette: That is right.

Mr. Code: Mr. Nuckols, your road has not seen fit to lay any long stretches of continuous welded rail, and there are many others like you. What considerations make you hesitate?

Mr. Nuckols: Our railroad is a little crooked in places, Mr. Moderator (Laughter).

I am very much interested in what has been said about the surface on the base of the rail—about getting off the upset material. We try to work on the top, as well. I don't know whether the panel is supposed to seek information, but I would like to know what these other fellows are doing in trying to get good surface on the top of the rail.

Answering your specific question, the terrain traversed by our railroad generally—except in a few instances along the river beds—is in mountainous territory, with heavy curvature, and we do not think at this time that laying continuous welded rail in such territory is the proper thing to do, because, as I said before, occasionally we have a rail fail in track, and it would be rather difficult, as well as costly (we estimate $60) to change out a 39-ft section of rail.

Mr. Code: As to your question about the top surface, I wonder if Mr. DeJarnette would want to comment on that? I presume you refer to unsatisfactory alinement?

Mr. Nuckols: Upset at the joint.

Mr. DeJarnette: We cut part of the upset off the base and grind the edge of the base to straight-edge alinement. Then we cut out the tie plate to accept the additional metal on the base.

Mr. Code: Mr. Racine, what is the additional cost of continuous welded rail, per mile, compared with jointed track, including the additional anchors?

Mr. Racine: We haven't developed anything too accurate on that. Statements have been made that continuous welded rail will cost all the way from $2000 up to $3000 per mile more than conventional rail. We expect to have some reliable information on this at the close of this year.

Mr. Code: Do you have any cost figures, Mr. DeJarnette?

Mr. DeJarnette: No.

Mr. Code: Mr. Racine, I believe I asked you before about removing the reinforcement, and you covered that in connection with the 78-ft rail.

Mr. Racine: I might say, Mr. Code, that Mr. Magee was satisfied with the fatigue tests as developed by the rolling-load tests, and is willing to advise anyone who desires to remove the upset metal from the base of 115 or 132-lb rail to do so, because the two sections have a great deal more reserve strength in them than is needed for today's service.

Mr. Magee is in the audience. Maybe he'd like to say something on that.

Mr. Code: Mr. Magee, do you want to comment at this time?

Mr. Magee: Mr. Racine has stated the situation accurately. We undertook to make some tests for the committee, to compare the effect of welds where the bulge was removed and where it was left on, and the fatigue test showed that removing the bulge from the base did increase the fatigue strength, because of the fact that it eliminates the change in section and the stress concentration effect that is produced at the bulge.

We were puzzled by the results in the drop test, and before we issued any final report on it, we thought that we would like to repeat the drop test and be sure of those results. However, as Mr. Racine stated, I feel that we have so much reserve strength in the 115 and 132-lb sections, from the standpoint of bending stresses, that we don't need to be too much concerned about some reduction in strength due to removal of the bulge.

Mr. Code: Thank you, Mr. Magee.

Mr. Lamport, have you heard of any road which has had difficulty with the bulge at welds, laid between the ties, running up on the tie plates, due to creeping?

Mr. Lamport: No. I have not.

Mr. Code: Mr. Racine, have you heard of any road that has had such difficulty?

Mr. Racine: When continuous welded rail was first installed, they didn't have it properly anchored, and they did have some trouble with the rail running to the extent that the bulge did get on top of the tie and the plate. However, in the last few years they have had no trouble at all because the rail has been properly anchored, and you don't get that run.

Mr. Code: I might comment that, although Mr. Lamport didn't hear about it, on our 78-ft rail we did have some trouble like that. Presumably, we didn't have enough anchorage.

Mr. Nuckols, many roads follow a definite program of buying new rail for their main line only, taking care of branch lines by re-laying rail from the main line when it has gotten to the point where the cost of maintaining line and service for high speed has become excessive. Would this consideration make you hesitate to embark on a program of continuous welded rail?

Mr. Nuckols: Definitely. On our railroad we use the released rail from main lines in maintaining our side or branch lines, as well as for newly constructed lines. If we were to go into welded rail to any great extent, we feel that it would be most difficult to handle this rail for replacement in branch lines or in newly constructed lines.

Mr. Code: Mr. DeJarnette, I gather you don't have that problem?

Mr. DeJarnette: No. We have to get total use out of the first application.

Mr. Code: Mr. Brown, you evidently prefer the 78-ft rail to continuous welded rail. What objections do you have to continuous welded rail?

Mr. Brown: We don't have any objections to continuous welded rail as such.

Probably I could sell Mr. Nuckols some 78-ft rail rather than continuous welded rail, to take care of his secondary lines. That is our problem. We think we can handle the 78-ft rail about the same as we handle the conventional 39 for our secondary lines.

Mr. Code: It fits in better with your maintenance cycle than the continuous welded rail, does it?

Mr. Brown: Yes.

Mr. Code: Mr. DeJarnette, what is your thinking about the problem of detailed fractures from shell in continuous welded rail?

Mr. DeJarnette: We have not had that problem since we adopted the 140-lb PS sections.

Mr. Code: In other words, you think it's a relatively minor problem?

Mr. DeJarnette: I do; yes.

Mr. Code: Mr. Brown, how does the problem of transposing rail affect your thinking about continuous welded rail?

Mr. Brown: With the 78-ft we don't have any difficulty. With continuous welded rail, I'm not in a position to say.

Mr. Code: Mr. Lamport, in case of a transverse break in a stretch of continuous welded rail, what is the likelihood of having it pull apart excessively in cold weather?

Mr. Lamport: It will, no doubt, pull apart to some extent, but if it is properly anchored, I don't think the pull-apart will be enough to cause a derailment. No doubt, you would feel it when going over it, but with the proper anchorage I don't think it would pull apart enough to create a hazard.

Mr. Code: Would you follow the practice of intermediate anchorage mentioned by Mr. DeJarnette?

Mr. Lamport: Yes. We have enough intermediate anchorage so we feel that the sections of (you might say) conventional anchorage in between will not be long enough for any great pull-apart.

Mr. Code: We have about 10 min now for discussion and questions from the floor. Would someone care to present a question to the panel?

C. J. Geyer (Retired vice president, construction and maintenance, C&O): From the various panel replies, Mr. Code, I understand they do not know the relative cost of 39 and 78-ft rail, nor do they know the cost of the continuous welded rail—that is, the annual cost per mile. I am wondering how any road can reach a decision as to the method or type of rail to use if they do not know the relative cost involved.

Mr. Code: I believe I neglected to ask Mr. Lamport a question about the annual cost of 78-ft rail versus 39-ft rail. I think he has some information on that.

Mr. Lamport: I think I answered you that the annual cost of maintenance on 78-ft rail, as compared with the 39-ft rail, is (on the basis of the best information available) $300 to $400 less per mile, per year.

Mr. Geyer: Is that just maintenance or does that take in the cost of the rail and the labor in laying it, etc.?

Mr. Lamport: The only difference you have in the initial cost is an estimated $297 per mile for laying, which includes labor and material. The maintenance cost is based on labor and joint replacement, welding rail ends, etc.

Mr. Code: In other words, that first cost of approximately $300 per mile would have a relatively small effect on the annual cost.

Mr. Lamport: That is correct.

Mr. Code: Mr. Racine, I'm not sure whether you gave us a relative maintenance cost for continuous welded rail. It seems to me you told us that this was under study, and that you did not have a conclusion as yet. Is that right?

Mr. Racine: That is correct. We have no accurate information, simply because there is no continuous welded rail that is ready to change out.

I think the Delaware & Hudson probably has had some experience, but it's going to require that we wait until some of these railroads that have continuous welded rail give us some figures on it.

As I stated previously, several railroads have indicated that the average cost is between $2000 and $3000 per mile more for continuous welded rail, but they feel that they will have a saving of probably $650 a mile in maintenance. They think the life of the rail will be increased, of course, in the continuous welded rail.

Mr. Code: Mr. DeJarnette, I believe you had some views on possible savings in connection with continuous welded rail.

Mr. DeJarnette: No detailed figures, Mr. Code. We laid our first continuous welded rail in 1950. It was tamped after laying. We have spent $460 in labor on that 2-mile stretch, and we don't anticipate any out-of-face working for the next 2 to 3 years.

Mr. Code: But you don't have any direct comparison of that track with the cost of maintaining jointed track?

Mr. DeJarnette: No. We're going to keep figures on that in comparison with the adjacent track.

Mr. Code: Any other questions from the floor?

Question: Has there been any increase in the cost because of the additional anchors made necessary by continuous welded rail, and have you considered a cycle replacement of the ties with continuous welded rail?

Mr. Code: Would you care to comment on that, Mr. DeJarnette?

Mr. DeJarnette: We anticipate cyclized maintenance on continuous welded rail. So far we have not had any tie renewals on this rail since it was originally installed.

Mr. Code: You don't anticipate that the additional anchorage is going to cause you any reduced life of your ties?

Mr. DeJarnette: No.

Mr. Code: If Mr. Ferris is in audience, we'd like to ask him a question. Mr. Ferris, would you like to comment on the problem of taking care of a broken rail in a long stretch of continuous welded rail?

P. O. Ferris (D&H): If the break occurs during the regular working hours when men are readily available, we go out with a saw, a power wrench and a drill and cut out a 39-ft piece and replace it with a 39-ft rail. If it happens during the night or at hours when the regular track force is not available, or when there may be a question of getting together the necessary number of men to take care of it, we have some 19-ft, 6-in rails that can be handled by small gangs, all drilled and ready to put in. We then go back at some advantageous time later and put in a 39-ft rail.

Mr. Code: You don't attempt to reweld the track? You leave the jointed rail in?

Mr. Ferris: That is correct.

Mr. Code: Is there any problem in taking care of expansion?

Mr. Ferris: No. Of course, you must try to keep the track the way it is found and don't let it move as you start to put in your rail to replace the section of welded rail removed.

Sometimes we would find failures of Thermit-pressure welds where the rail pulled apart at the weld 1½ in to 1¾ in, the rail running back through the fastenings in each direction 3 to 3½ rail lengths.

The policy is to keep the rail in tension wherever it can be done. Therefore, care must be used to hold the stretch of rail exactly as it is found by tightening the clip bolts to prevent it from further movement when the rail is inserted to replace the section of welded track removed.

Mr. Code: Thank you very much, Mr. Ferris.

Are there any further questions from the floor? If not, I want to thank the members of the panel very much for their help, and our audience for their kind attention and their contributions to the discussion.

President Miller: Mr. Moderator, Mr. Lamport, Mr. Brown, Mr. Nuckols, Mr. Racine and Mr. DeJarnette, we greatly appreciate your discussion. Your panel, unlike some TV panels I have seen, had no secrets—and the participants received no prizes.

The ideas expressed in your discussion are truly statements of fact based on the actual experience of several major railroads in this country. While our experience on the Canadian Pacific in the use of 78-ft rail has not been very extensive, it is quite evident that no serious difficulties have been experienced. There seems to be an economy in maintenance costs, with no unexpected increase in cost of material or any serious evidence of defects.

The use of continuous welded rail is being progressed on a moderate scale. There appears to be some fear of the effect of temperature on track work, such as surfacing and heavy tie renewals. There are also a few problems, such as anchorage, insulated joints, upset material on the base, and cost of changing rail in curved territory. But we, as an Association, are most interested in these two problems which you have discussed. and if you will continue to keep us informed through your committee reports, it will be, indeed, a great help to the industry.

The attendance and careful attention given to this panel discussion indicate that this method of discussing a problem is most acceptable. I hope we can do this again at a future convention.

The presentation of the panel discussion completes the technical phase of our annual meeting. I am sure that great benefit has resulted from the presentation of our committee reports and special addresses, and I want to take this opportunity to thank again all of those who participated in any of these features.

Before we begin the closing session of our convention, I should like to announce—primarily for the benefit of the newly elected members of the Board of Direction—that there will be a Board luncheon today at 12:45, in Dining Room 9, to be followed by a meeting of the Board in Room 6 at 2 pm.

As a matter of record, I should like to say that the registration at this convention has been 2375, which I believe is an all-time high.

Closing Business

I now call to order the closing business of this convention. Is there any other business to come before us?

F. S. Schwinn (Missouri Pacific): Mr. President, may I have the privilege of the floor?

Mr. President, members of the Association, ladies and guests: In these days (probably I should say years) of mistrust and distrust between nations, of suspicion, of hatred, of animosity between peoples of this earth, it is a distinct relief to note the feeling of brotherhood, of neighborliness, between Canada and the United States. That feeling, gentlemen, has been wonderfully shown by your president of this past year—an officer of the Canadian Pacific Railway. It is proper that this Association should show its appreciation of that man's endeavor to stifle—and to erase—that spirit of animosity that is now so very, very noticeable on this earth.

In showing our appreciation, this Association has honored me with the privilege of presenting a lasting token to him, a token of appreciation in this plaque. I will read every word of its inscription so that you will know how we all feel.

"The American Railway Engineering Association records its grateful appreciation to George Webster Miller for his able administration of the affairs of this Association during his term as President, 1954–1955."

Mr. Miller, I can only add for the Association—well done, good and faithful servant! (Applause)

President Miller: Mr. Schwinn, you were very kind in those remarks.

I recall a motto that we have in one of our engineering associations in Canada. It is this: "Silent service is not enough." I throw that to you as a challenge in our own railway association work, and to you as citizens.

There are times and occasions in the lives of most men that they treasure and want to remember always. My year as president of this Association has been such a time. I have enjoyed it, and all that it has brought me, more than I can tell. I am very happy to receive this plaque, and I will keep it as a constant reminder of a very happy period in my life. (Applause)

The close of our 1955 annual meeting marks the end of service on the Board of Direction of one of our past presidents, Mr. C. J. Geyer, retired vice president—construction and maintenance, Chesapeake & Ohio Railway, under the present practice wherein past presidents remain on the Board of Direction for only two years after their terms as president.

The Association is deeply indebted to Mr. Geyer for his long and valued service to the Association in an official capacity, for his special service on many Board committees, and for his always sound counsel.

I should be pleased if Mr. Geyer would stand and be recognized. (Applause)

The terms of office of four other members of the Board of Direction terminate with this annual meeting. I refer to Directors M. H. Dick, editor, Railway Track and Structures, and western editor, Railway Age; E. E. Mayo, now vice president, Southern Pacific Pipe Lines, Inc., formerly chief engineer, Southern Pacific Company; S. R. Hursh, chief engineer, system, Pennsylvania Railroad; and Ray McBrian, engineer of standards and research, Denver & Rio Grande Western Railroad. All of these men have served your Association diligently and well.

Mr. Dick, Mr. Mayo and Mr. Hursh are retiring from the Board after a term of three years. Will these gentlemen please stand and be recognized? (Applause)

Mr. Hursh was not able to be present today.

Mr. McBrian, as you probably know, is remaining on the Board, and I will recognize him later.

At this time I also want to express my deep appreciation to Mr. Laffoley, chairman of the arrangements committee, and to the members of his committee, for only by being on the inside—as I have been for the past year—can one fully appreciate the magnitude of the details which are planned and carried out by this committee in order that our convention may be a success.

While all members have served diligently and well, I want to make special mention of one member of that committee who has served diligently and well for the past 30 years, and who will retire from the committee at the close of this convention. I refer to Mr. Guy P. Palmer, retired regional engineer, construction and maintenance, Baltimore & Ohio–Chicago Terminal Railroad, who has been a member of our Committee on Convention Arrangements since 1925, and who served as chairman during the administrations of President Bond, 1941–1942, President Layng, 1944–1945, and President Chinn, 1947–1948.

At the meeting of the Arrangements Committee on Monday of this week, Mr. Palmer's resignation was accepted as of the close of this convention, and he was immediately and unanimously elected to the honorary status of Honorary Member of the committee, an honor reserved only for those who have rendered long outstanding service to the Association through the committee.

As tangible evidence of this honor bestowed upon Mr. Palmer, I would like to present him with an engraved pocket card which reads, "This card signifies that Guy P. Palmer has been awarded the honorary degree of Honorary Member of the Committee on Convention Arrangements of the American Railway Engineering Association, for long-standing, meritorious service to the committee."

Mr. Palmer, will you please come forward? (Applause)

G. P. Palmer (B&OCT): Thank you very much. (Applause)

President Miller: While recognizing people who have played an important part in the functioning of this convention, I would be negligent if I did not make special mention of the group of ladies, under the direction of Mrs. Howard, who gave so kindly of their time to serve as hostesses in the ladies' registration room. The Association is appreciative of the work done by these ladies. (Applause)

It is now my great privilege and pleasure, as your retiring president, to introduce to you the Association's new officers for the ensuing year.

Our senior vice president for the year ahead is Mr. William J. Hedley, assistant chief engineer, Wabash Railroad, who, under the Constitution, automatically advances to this position from that of junior vice president. Mr. Hedley, will you please come to the platform? (Applause)

Your newly elected junior vice president is Mr. Ray McBrian, engineer of standards and research, Denver & Rio Grande Western Railroad. Mr. McBrian has been a director of our Association since March, 1952, and is known to most of you through his other widespread activities.

Mr. McBrian, will you please come to the platform and stand here with Mr. Hedley? (Applause)

Mr. Hedley and Mr. McBrian, I congratulate both of you upon your elevation to high office in our Association, and wish for you every success in your efforts in behalf of the Association in the years immediately ahead. You have contributed much to the Association in the past, and I am sure we can expect much from you in the future.

As your president for the year ahead you have elected Mr. G. M. O'Rourke, assistant engineer maintenance of way, Illinois Central Railroad. I have asked that past presidents Chinn and Grove escort Mr. O'Rourke to the platform. (Applause)

Mr. O'Rourke, it is a great honor for me to proclaim you the newly elected president of the American Railway Engineering Association. I turn over my responsibilities to you with the greatest of confidence in your ability to carry forward the objectives of the Association in the year ahead.

(President-elect O'Rourke assumed the chair.)

President O'Rourke: Mr. Miller, it is a privilege and honor to succeed you, sir, as president of this Association. Your administration has been one to be proud of. Speaking for the officers and members of this Association, we thank you for a job well done.

Members, ladies, guests of the Association, and friends—and truly, you are my friends, or otherwise you would not have reached so far down on the totem pole to get a chief to manage the affairs of this Association for the ensuing year—after 50 years of maintenance engineering experience, to be elected to the presidency of this Association is probably the finest thing that has ever happened to me. This moment will remain a highlight in my memory, to sustain me in the days to come.

As I look back over the years that I have been a member of this Association, and recall the Illinois Central men who preceded me in this office, I am filled with conflicting emotions, ranging from pardonable pride to deep humility. The organizer and first president of this Association was John F. Wallace, chief engineer of the Illinois Central. Fifty years later C. H. Mottier served as president, during our Golden Jubilee year. Included between those two men from my railroad who were honored by the Association, were L. C. Fritch, A. S. Baldwin, H. R. Safford, L. A. Downs, G. J. Ray, D. J. Brumley, and L. W. Baldwin. Some of you with long beards and white hair—or no hair at all—can remember most of those men.

A. F. Blaess was treasurer for several years. Neal D. Howard began his railroad career on the Illinois Central.

Illinois Central men who were directors included Curtis Dougherty, C. R. Knowles, F. L. Thompson, and E. L. Crugar.

Other Illinois Central men have been active committee members, and many have served as chairmen. Truly, the Association has meant a great deal to Illinois Central men. They have been active in its affairs, and they have received great benefit in return.

I worked for all of those mentioned except J. F. Wallace, who was before my time. George Ray and Curtis Dougherty left the Illinois Central before I caught up with them.

When I think of the engineering stature of those men and of the other men from other railroads who have served in this capacity, I feel humble and inadequate. I am truly standing on the shoulders of giants. Those men set up a record of accomplishment that is going to be hard to follow, but with the grace of God and the continued encouragement of a little colleen sitting up there in the balcony with one of our lovely daughters, with the advice and counsel from the past presidents to whom I referred, and from our splendid Board of Direction, with assistance from Gerald Magee and his staff, and our friends of NRAA, guided by our peerless Secretary, and with your help and cooperation—and I mean your help—I shall try hard to carry on and progress the work of this great organization. I am deeply grateful to you, and I thank you very much. (Applause)

Mr. Mottier: Mr. President, I request the privilege of the floor.

Mr. President, and "futures," and "has-beens," and guests, members and ladies: George and I both subscribe to this "Silent service is not enough" philosophy. I don't think anyone has accused me of going too strong on this silence stuff.

I have a very pleasant function to perform at this time. To allay your suspense, I will tell you that I am going to give George a gavel. I have said that because it is essential that I give a little background in this presentation. I am glad to make this presentation for my own personal interest and also for the more than 100 members of our organization, and for the many friends that George has on the Illinois Central. We want to wish him well on his new job. We want to recognize his authority as president of this Association, and we want to show our friendship and esteem for him.

In Mr. Crump's allusion yesterday to "Maple Syrup", I learned something more from our Canadian friends. (You have to learn two new things every day when you get as old as I am, because you forget things.) I'd like to spread a little of that maple syrup on George, and I hope that it will be sticky and sweet, and maybe we'll let a few drops fall on the Main Line of Mid-America.

I didn't know that George had looked up all these records, because, had I known that, it would have saved me a lot of time. When our Canadian friend, Mr. Crump, took justifiable pride yesterday in calling attention to the fact that four Canadian Pacific engineers had been presidents of this Association, I thought this morning I would check up, so I called Allen Sams at the office and told him to get out the Golden Jubilee yearbook and check up as to what roads, if any, beside the Illinois Central, had exceeded that maximum of four. In due course he called back and said his check indicated that four was the maximum number of presidents furnished by any other railroad. Now, George had quite a gang, but he was taking in some of IC alumni. But, actually, we had six who were bona fide employees of the Illinois Central when they were elected to the presidency, so I think that we have contributed much. We're proud to have done this, and we're glad to have been so recognized.

Now, about this personal satisfaction, I know that Margaret (Mrs. O'Rourke) will remember some of these things, as will George. If I had time, I would like to tell you quite a few things that happened many, many years ago. As Bobbie Burns would say, George and I have "clim the heel together."

I don't remember when I met George first, but he gave me some very good swimming lessons at the old beach in Jackson Park, there by the German Building, which some of you old, gray-headed and bald-headed fellows will recall—I think it was about 43 years ago. I don't remember the first job that I had with George. However, it was over 40 years ago that they sent George and me, as cubs, down to Carbondale, Ill., to check up on the Big Muddy bridge, a new arch we had just built, to find out if it was settling. I think George ran the instrument, and I held the rod. He was my superior on that job. To satisfy your curiosity, that bridge hasn't settled in the past 40 years, and it's still doing excellent service.

But, George, neither you nor I surmised for one minute at that time that on March 17, St. Patrick's Day, 1955, you and I would be up here together, and I would be pouring this "maple syrup" on your head. (Laughter)

I think it is quite appropriate, and to the satisfaction of both Margaret and Alice (daughter), as well as George, that this happens to be St. Patrick's Day. If any of you don't get the connection, and will come up here after we adjourn, I'll explain it to you. (Laughter)

There is one other thing I would like to say. I get a lot of satisfaction out of giving George this gavel because I think I am probably the only past president in this Association who got a gavel who didn't have it given to him when he was inaugurated.

I think Armstrong Chinn will remember this. Walter Lacher and I had quite a laugh about it yesterday. About 10 or 11 o'clock on Thursday, when Armstrong Chinn was to present me a gavel, he got a telegram about a strike on his railroad, and made a quick getaway. After the convention, Walter Lacher came over to me and kind of bashfully, and with apologies, slipped me a box with the gavel in it.

I want to say one other word. I have learned a lot about making gavels. I could give you quite a treatise on the subject, and tell you some things not to do.

I didn't know anything about making gavels, so when we decided to make this gavel, we went into a huddle. We thought we would make it out of something that had a little sentiment connected with it.

Of course, I couldn't figure out how you could get this continuous silver band on this gavel, when both ends are bigger than the diameter of the silver band. Now, if any of you folks don't know how that is done, and want to know, you can come up and I'll tell you afterward, because it takes a long time to tell how that is done.

We decided that we would get a piece of wood out of some old building that was built at the time our line was constructed. Incidentally, our chief engineer then was Roswell B. Mason. That was before the AREA, but he was the first president of the Western Society of Engineers.

We arranged with Mr. Van Arsdalen (division engineer at Carbondale) to send in a nice piece of white oak that we had cut out of one of our old stations built back in the Fifties. He sent in a piece almost as big as a tie to make this gavel.

We had it turned out. Earl Snyder (assistant to chief engineer) was running the thing. About a week later he said, "I don't believe this gavel will be any good." He brought it in, and it had some of the most beautiful cracks in it you ever saw. A gum tie has nothing on white oak when it comes to making gavels. It can crack beautifully.

This is the third gavel that we made. We realized that we had to make it out of some close-grained wood, and we wondered how we could get any mahogany or walnut that was used 100 years ago in building some station. Someone learned that Charlie Weller (division engineer, Chicago terminal) had found a walnut tie on the suburban tracks a few years ago, and had told the boys to leave it at 26th Street.

Well, I thought that was all a frameup in order to make a good story here, but I checked into it, and they tell me that it's the truth, and I'm accepting it as the truth. We took that solid walnut tie and made his gavel out of it. Incidentally, except for the band, it was made by our own people.

George, it gives me great satisfaction, on the part of your friends on the Illinois Central, to present you with this gavel as a token of our esteem, and with it we wish you the best of luck and success. We know that you will be a credit to the Illinois Central, and we hope you won't be the last IC president of the AREA. (Applause)

President O'Rourke: Thank you, sir. I shall cherish this the rest of my days. I thank you, and my other friends on the Illinois Central who made this possible. I think I'll take it home and wrap a green ribbon around it and put it up on the bookcase. And if this weren't such a solemn occasion, I would say "What a great St. Patrick's Day in the morning it is when a neutral Swiss presents a neutral Irishman with a shillalah." (Laughter and applause)

Thank you very much, Mr. Mottier.

N. D. Howard: Mr. President, may I have the privilege of the floor?

President O'Rourke: You may, Mr. Howard.

Mr. Howard: I, too, have something I want to present to our new President. I hold here in my hand a solid gold emblem of this Association, which I want to give him on behalf of you members.

This was not to be my honor this year. We planned it otherwise. Someone else had been delegated, but fate was not to have it that way. Sometimes fate is very kind.

You in the audience will understand this when I tell you that your president-elect was my first boss on my first railroad job on the Illinois Central—back in 1922. He was division engineer, and I, to him, was Rodman Howard. He will recall, I'm sure, that both of us at that time were already working for the AREA—he much earlier, of course, than I. Now he is my boss again, and we are still working for the AREA.

In memory of those earlier days, of my high regard and affection for him, and for his loyalty to and love for the American Railway Engineering Association, I am proud to present him, on your behalf, with this beautiful gold emblem of our Association. I have the utmost confidence that he will wear it with both honor and distinction. (Applause)

President O'Rourke: Thank you, Neal. Thank you for the very pleasant and cheerful manner in which you presented me with this badge of honor. I shall never look upon it without recalling our friendship.

I believe now is the time for me to take up the duties of the Association, and it is my privilege now to introduce to you the four men whom you have elected as new members of your Board of Direction. I will ask each one of them to come forward and stand in front of the speaker's table as his name is called.

Mr. E. J. Brown, chief engineer, Burlington Lines, Chicago. (Applause)

Mr. F. R. Woolford, chief engineer, Western Pacific Railroad, San Francisco. (Applause)

Mr. R. H. Beeder, assistant chief engineer, system, Atchison, Topeka & Santa Fe Railroad, Chicago. (Applause)

Mr. C. J. Code, assistant chief engineer—engineer of tests, Pennsylvania Railroad, Philadelphia. (Applause)

Gentlemen, I congratulate you upon your election as directors of this Association, and welcome you to the Board of Direction. I know that you will enjoy your association with the Board for the next three years, and will bring much of value to its deliberations.

Thank you very kindly.

(Announcements by President O'Rourke.)

President O'Rourke: If there is no further business to come before this meeting, I now declare the Fifty-Fourth Annual Meeting of the American Railway Engineering—

Mr. Geyer: Hold it. May I have the privilege of the floor?

President O'Rourke: You certainly may.

(At this point Mr. Geyer presented Mr. O'Rourke with some potted shamrocks.)

President O'Rourke: Again I will say, if there is no further business to come before this meeting, I now declare the Fifty-Fourth Annual Meeting of the American Railway Engineering Association adjourned.

(The meeting adjourned at 12:45 o'clock.)

A

MEMOIRS

MEMOIR

John Morrice Roger Fairbairn

Died May 27, 1954

John Morrice Roger Fairbairn, retired chief engineer of the Canadian Pacific Railway, and a past president of the American Railway Engineering Association, died at his home in Westmount, Que., Can., on May 27, 1954, in his 81st year after a short illness. He is survived by his wife, the former Hanna Louise Macfarlane, three daughters, Mrs. M. Beresford Hamilton, Mrs. M. M. Mackenzie, and Mrs. F. R. Windsor, and 10 grandchildren. His only son, J. M. Fairbairn, died in 1952.

Mr. Fairbairn was born in Peterboro, Ont., on June 30, 1873, son of Thomas McCulloch Fairbairn and Jane (Roger) Fairbairn, both of Peterboro. After his early education in Peterboro he was graduated in civil engineering from the School of Practical Science, University of Toronto, Toronto, Ont., in 1893. During his university course, summer vacations were spent on railway locations and other engineering work. After graduation he worked for various non-railway interests for eight years, during which

J. M. R. Fairbairn

he qualified as a licensed land surveyor in British Columbia, and was in private practice as a civil and mining engineer and provincial land surveyor at Kaslo and Greenwood, B. C., for about two years.

In August 1901 John Fairbairn started what turned out to be a notable career with the Canadian Pacific Railway. Between 1901, when he started at the bottom, and December 21, 1938, when he retired from the top, he occupied various positions, being successively assistant engineer, division engineer, principal assistant engineer, engineer maintenance of way, assistant chief engineer, and chief engineer, to which latter position he was appointed on July 1, 1918.

Some idea of the importance of his position as chief engineer may be sensed by the fact that in the 20 years during which he was chief engineer, the company spent approximately $200,000,000 for additions and betterments, in connection with which the chief engineer was responsible. He took an intense interest in important bridge work, grade separation work, and hotels, but this in no sense reflected a lack of interest in less spectacular projects. When a junior had to discuss a company project with the "chief", that junior had to "know his stuff."

In spite of the heavy demands of his railway duties, Mr. Fairbairn found time to do much for the benefit of the engineering profession. In the more public phase of this work he was a member of the Institute of Civil Engineers of Great Britain, and a past councillor and chairman of the Canadian Advisory Board. He was an honorary member of the American Society of Civil Engineers and chairman of the Canadian Membership Committee. He was a member and past president of the Engineering Institute of Canada and was recipient of the John Kennedy Medal, which is the highest honor the Institute can bestow. His university honored him by giving him the honorary degree of Doctor of Science, and last, but by no means least in his estimation, he received from the American Railway Engineering Association the privilege of being a past president, and the honor of an honorary membership.

Mr. Fairbairn joined the AREA in 1910 and was elected president of the Association for 1925–1926, after previous service as a director and vice president. He had served on the following committees: 4—Rail, 1917–1930, being vice chairman 1922–1924; 5—Track, 1912–1916; 24—Cooperative Relations with Universities, 1924–1933; and 26—Standardization, 1920–1926.

Mr. Fairbairn was always a most enthusiastic advocate of the advantage of membership in the AREA. During the ceremony at which honorary membership was conferred on him he said in part, "I have never been in contact with any technical organization which began to give its members the same interest in their daily work that this Association does . . . It gives him a chance to exchange his views, share his experiences with other members. From that he gains a great deal, gains experience, and gains an intimate knowledge of fellow workers in his own field."*

Mr. Fairbairn took a keen interest in the affairs of the Association and it was a pleasure to hear him talk on any subject. He possessed to an unusual degree the esteem and confidence of the Association's officers and membership. They, therefore, wish to express in this memoir their sincere and deep sorrow in the passing of a personal friend. and to his family extend their deep sympathy for the loss they have sustained.

Behind the scene Mr. Fairbairn was always helping other engineers in need, and especially young engineers, or giving fresh heart to the despondent. On his extensive and numerous journeyings over the lines of the system he was welcome everywhere for his kindly courtesy and sound advice. He will be long remembered on the CPR.

In private life Mr. Fairbairn had many friends. He was a member of St. Andrews United Church in Westmount, and a supporter of all its activities. He played golf occasionally, but like all men in positions such as he held, he did not have time to become a champion. He had a great love for dogs and they in turn loved him. At his summer home on an island in Stony Lake he had a speed boat in which he took keen pleasure. The lake, named for its rocky shores, had numerous submerged rocks, but John Fairbairn had them all charted and loved to "let his boat out" in spite of them.

John Morrice Roger Fairbairn made good use of his talents.

L. C. Fritch, *Chairman,*
G. J. Ray
D. J. Brumley
R. B. Jones
Committee on Memoir

* AREA Proceedings, Vol. 47, p. 573.

MEMOIR

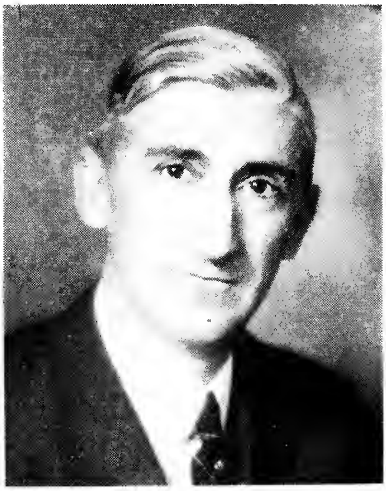
Edgar Morton Hastings

Died November 21, 1954

Edgar Morton Hastings died on November 21, 1954. Thus ended the distinguished career of a man of gifted personality, whose devotion to his profession, his religion and his family was equaled by his civic consciousness and deep sense of obligation to help build a better community. Mr. Hastings was peculiary well fitted to do these things. First of all, because of his innate and sincere liking for people, which together with his uncompromising principle—his readiness to "stand and be counted", to use his own expression—quickly inspired a reciprocal confidence and esteem.

Mr. Hastings was born May 5, 1883, in Lutherville, Maryland, the son of Robert John Hastings and Ada (Heilig) Hastings. His formal education was obtained at Baltimore City College and Baltimore Polytechnic Institute, from which he was graduated. He was an honorary alumnus of Virginia Military Institute, to which he was contact member and patron of the student chapter of the American Society of Civil Engineers.

Edgar Morton Hastings



Early in his professional career it became obvious to his associates that Edgar Morton Hastings possessed in rare degree those qualities which were destined to put upon him heavy demands of responsibility and service, and justly to bring him high honors. These followed immutable laws and thus were proportioned in equity. Earliest, perhaps, among those who observed these qualities was the current chairman of the board of an eastern carrier who was transitman on the Baltimore and Ohio Railroad survey party of which young Hastings was rear-chainman, who has stated ". . . in this early period he exhibited earnestness, industry, the urge to do good work and progress, and the faculty of getting along well with his associates—attributes which have been so marked in his succeeding years."

In the course of this career constructive work and energy were given to practically all activities of the two professional societies nearest his heart—the American Railway

Engineering Association and the American Society of Civil Engineers. His service with the former, extending over a period of 42 years, was particularly notable on its Committees on Yards and Terminals, Cooperative Relations with Universities, and Standardization, the latter of which he was chairman. He served also as a director, 1931–1934, as vice-president, 1937–1939, and as president in 1939–1940. In further recognition of his distinguished leadership, in 1950 Mr. Hastings was made an Honorary Member of the American Railway Engineering Association.

Mr. Hastings' service to the American Society of Civil Engineers was equally unselfish and meritorius. He was a member for 32 years, during which period he served as president of the Virginia section, as vice-president of Zone II in 1943–1944, and as president of the National Society in 1947.

Other professional affiliations of Mr. Hastings included the American Society for Testing Materials, the Engineers Club of Hampton Roads, Engineers Club of Virginia, and the Central Virginia Engineers Club, of which he was a past president. All of these held his active interest, and his hand and counsel are reflected in many of their accomplishments.

In his service to the Richmond, Fredericksburg and Potomac Railroad, which began in 1903, Mr. Hastings rose progressively through subordinate posts until he became chief engineer in 1922. His administration there was marked by many noteworthy achievements. These included the complete rehabilitation of the property in the post-world-war I period, subsequent large-scale improvements, the replacement of station and bridge facilities at Fredericksburg, Virginia, with modern structures, extensive bridge and drainage programs, the adoption of modern maintenance policies, and the use of heavy-section, continuous welded rail in main track.

Advantage of the talents and qualifications of Mr. Hastings was taken by the United States Government in 1948, when he was selected by the Economic Cooperation Commission to inspect and report on the three principal railroads in China. This project he performed in the same exemplary manner and spirit which marked his service to his profession and the railroad industry.

Aside from professional interests to which he gave in generous measure his time and energies, Mr. Hastings' other interests were considered by him of equal or greater importance. These were his church, his family and his work among youth, particularly with undergraduate engineers. These received a full measure of his devotion.

Together with holding high lay offices in his church, he was for years a teacher of young men in the church school. Himself an example of proper early training, and a firm believer in the thesis that youth comprises the hope of the world, he held himself constantly available for counsel, ever alert to offer sympathetic understanding of the many personal problems brought to him by young men who had come to reciprocate his confidence. Many men going their separate ways today can recall with gratitude the sound advice which he responded when sought.

There is no gauge, unfortunately, for recording in absolute terms the influence of a man upon his fellows. But in the case of Edgar Morton Hastings this influence can be attested by a wide circle of associates who knew the sincerity and warmth of his endearing personality.

Mr. Hastings sense of responsibility extended into all of his spheres of interest. However heavy the demands upon his time, his interest in his community was never diminished. Unselfishly, he rendered many services to his city, serving as a member of the City Planning Commission and as chairman of the Board of Zoning Appeals.

Regardless of his busy schedule, Mr. Hastings appreciated the value of family relationships and always found time for the companionship of his sons. It is an interesting commentary to note that until he suffered a heart disturbance at the age of 55, it was the rule rather than the exception for him to start the day in summer with an early morning swim with the two boys, and quite frequently to play a set of tennis with them in the late afternoon.

In his concern for the welfare of our country, quite frequently in spoken and written word, Mr. Hastings expressed his views on political matters and the trend of government at the national level. He deplored what he termed "the drift toward state socialism", the gradual loss of liberties and submergence of the individual into the all-powerful state.

A man of exceptional understanding and personality, and possessed of high courage, Mr. Hastings stood firmly on principle. He was no reactionary conservative, but held the view expressed by Patrick Henry, whom he quoted on occasion: "I have but one lamp by which my feet are guided and that is the lamp of experience. I know of no way of judging the future but by the past."

In his passing the engineering profession has lost an eminent practitioner, the church a loyal supporter, the community a good citizen and sound counseler, and the young engineer a sympathetic adviser. His death creates a void among the leadership of the American Railway Engineering Association.

He occasionally quoted St. Paul, whose life he followed and admired. No more apt quotation than St. Paul's statement to Timothy when death was imminent, could be applied to Mr. Hastings, "I have fought a good fight; I have finished my course; I have kept the faith."

C. J. Geyer, *Chairman,*
G. D. Brooke
W. P. Wiltsee
A. R. Wilson
F. R. Layng
Committee on Memoir.

MEMOIR

Frank Lee Nicholson

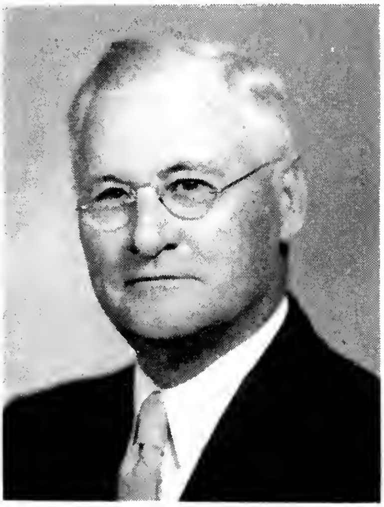
Died May 24, 1954

Frank Lee Nicholson, retired chief engineer of the Norfolk Southern Railway, and a charter member of the American Railway Engineering Association, died on May 24, 1954, at his home in Norfolk, Va., after an illness of several months. He is survived by his wife, Mrs. Ada Parker Nicholson, and a son, Clyde Parker Nicholson, who now resides in Germany.

Mr. Nicholson was born August 12, 1868, in Portsmouth, Va., the son of Francis James, and Catherine Olevia Culpepper Nicholson. He attended the public schools in Portsmouth and the Suffolk Military Academy.

His first job was with the Atlantic and Danville Railroad. Later he was associated with the Wilmington, New Bern and Norfolk Railroad, and the Raleigh, Charlotte and Southern Railroad, when it was purchased by the Norfolk Southern. His association with the Norfolk Southern was marked by a series of promotions, culminating with his

F. L. Nicholson



elevation to chief engineer, a position which he held for 38 years until his retirement May 31, 1947. Also during this time he was consulting engineer, July 1 to November 30, 1918; and chief engineer December 1, 1918, to April 30, 1919, for The Virginian Railway. During the Federal Administration of Railroads he served in Washington as a representative of the Southern Region on a committee for drafting rules and working conditions for maintenance of way employees and shop labor.

Mr. Nicholson, joined the American Railway Engineering Association in 1899 as one of its charter members, and had been a member of the following committees for different periods of time: 5—Track, 7—Wood Bridges and Trestles, 11—Records and Accounts, 12—Rules and Organization, 20—Contract Forms (chairman 1932–37), and 26—Standardization (chairman 1939–42). He was a director of the Association for three years and became a Life Member in 1936. His work on all of these committees was outstanding. His earnestness, zeal and interest will long be remembered by his associates.

Mr. Nicholson was a director of the American Society of Civil Engineers, 1929–31, and was a member of the Society of Military Engineers, and the Engineers Club of Hampton Roads. His fraternal affiliations included membership in Corinthian Lodge No. 266 A. F. and A. M., and the Odd Fellows.

In addition to his railroad and other duties he served for 17 years on the Norfolk Planning Commission, 6 years of which he was its chairman. He did much to plot the orderly growth of the city, particularly its public improvements and major highway planning.

Mr. Nicholson was a member and deacon of the Freemason Street Baptist Church, and at the time of his death was chairman of the Finance Committee of its church school.

In the passing of Mr. Nicholson the Association, the railroad world, the community in which he lived, and his many friends have lost a cultured Christian gentleman who had done much to make the world a better place in which to live. He leaves behind the respect and love of many, who feel deeply the great loss in his passing.

W. R. Swatosh, *Chairman*
E. M. Hastings, Jr.
W. D. Kirkpatrick
G. W. Patterson
Committee on Memoir

REPORT OF THE SECRETARY

March 1, 1955

To The Members:

In every respect, your Association has had another good year—not a startling year, but a year of accomplishments, a year of further growth, and a year, the close of which found it in a healthy financial condition. That such can be said of a year of declining railway revenues, and a slackened pace of both railway construction and maintenance, is significant. But such a situation did not "just happen." It was the result of a continued high level of membership interest, the willingness of committee chairmen and subcommittee chairmen to give freely of their time and effort, and a series of measures on the part of your officers to stimulate and appropriately recognize that effort; to bring the benefits of membership to the attention of eligible non-members on the railroads; and to hold expenses to the lowest practicable level.

MEMBERSHIP

Membership in the Association as of February 1, 1955, stood at 3278, a net gain of 21, continuing further the unbroken record of membership increase each year since 1944. This net gain was one more than in 1953, and while it was not as large as in the three years prior to 1953, which averaged 57, it is significant nonetheless in view of the voluntary personal obligation assumed in membership, the large losses in membership sustained each year through deaths and other causes, and the fact that 1954, due to economic conditions generally, was a year of lower railway earnings, activity and employment.

The most significant aspects of the membership record during the last year—one favorable and the other unfavorable—are the larger number of new members taken in in 1954 over 1953 (231, compared with 203), and the further drop in the number of Junior Members in the Association from 261 in 1952, to 220 in 1953, and to 187 in 1954.

Commenting first on the increase of 28 in the number of new members taken in during 1954 over those taken in during 1953, it can be said that this increase, too, did not just happen; it might well have been otherwise. When it became evident early in September that the number of new members coming into the Association was not holding up to that of recent years, the secretary was authorized by the Board Committee on Membership to address a letter to the chief engineeering and maintenance officers of the railroads, asking three questions—whether they thought their roads were adequately represented in the AREA; whether it was possible that there were men in their organizations who were not aware of the benfits inherent in Association membership, especially among their newer and younger technical employees; and whether they would be willing to canvass the situation and recommend men for membership.

The results of this letter, which was sent out during the last week in September, were significant in many respects—the interest taken by those who received it, showing their solicitude for the Association and their men; the long list of prospective members furnished to your secretary; and the steady flow of applications for membership which followed. By late December, more than 200 names had been suggested for membership, and as the result of personal invitations from the secretary's office, 101 applications had been received. By February 1, 1955, 57 additional applications had been received. Of these 158 applications, 107 had been approved for membership by the Board of Direction as of February 1, while 51 were still in the process of being acted upon, and are, therefore, not included in the membership total of 3278 as of February 1.

Committees of the Board of Direction
1954

Outline of Work

Ray McBrian (chairman), B. R. Meyers, C. J. Geyer, C. H. Sandberg, W. H. Giles.

Personnel of Committees

G. M. O'Rourke (chairman), Ray McBrian, C. J. Geyer, C. B. Porter, H. R. Peterson.

Publications

M. H. Dick (chairman), Wm. J. Hedley, E. E. Mayo, H. B. Christianson, C. H. Sandberg

Manual

Wm. J. Hedley (chairman), M. H. Dick, C. G. Grove, W. H. Giles.

Membership

E. S. Birkenwald (chairman), C. G. Grove, G. E. Robinson, H. B. Christianson, H. R. Peterson.

Finance

B. R. Meyers (chairman), G. M. O'Rourke, S. R. Hursh.

Special AREA Services

S. R. Hursh (chairman), E. E. Mayo, E. S. Birkenwald, G. E. Robinson, C. B. Porter.

Forty-one new Junior Members were taken into the Association during the year ended February 1, 1955, which compares with 39 for the preceding year. However, due to the transfer of 17 Juniors to the grade of Member and the dropping out of membership of 57 others, there was a net loss of 33 Junior Members in the Association, bringing the total of such members in the Association down to 187, compared with the total of 220 the previous year, and the record number of 261 Juniors in the year ended February 1, 1953.

In the light of the considerable number of junior engineers employed by the railroads each year, applications from only 41 of them for Junior Membership in the Association, as was the case in 1954, would appear to be far from adequate, and far from representing a desirable situation either from a standpoint of the young engineers themselves or their railroads.

Assuming that these young technical graduates entering the service of the railroads have done so to make the most of it for themselves and their companies, it seems reasonable to assume that, fully apprised of the benefits of Association membership and the small cost involved, as many as 90 percent of them would apply for Junior Membership. If this is true, it is incumbent upon the Association to devise a foolproof plan wherein the value of AREA membership is early brought to the attention of every junior engineer employed by the railroads.

The changes in the status of membership during the past year are set forth in the following tabulations:

Membership

(February 1, 1954, to February 1, 1955)

Members on the rolls February 1, 1954	3257
New members	231
Reinstatements	14
	3502
Deceased	46
Resigned	56
Dropped	89
Net Loss Juniors (transferred 17; dropped 57; additions 41)	33
	224
Net gain	21
Membership February 1, 1955	3278

Membership Classification as of February 1

	1949	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*
Life	325	339	355	361	375	401	436
Member	2263	2276	2243	2284	2312	2366	2381
Associate	275	280	274	288	289	270	274
Junior	145	158	220	257	261	220	187
Totals	3008	3053	3092	3190	3237	3257	3278

The ranks of the living charter members of the Association were thinned during the past year by one through the death on May 24, 1954, of Frank Lee Nicholson, who had served as a director in 1937, 1938 and 1939. A memoir to Mr. Nicholson appeared in Bulletin 517 for September–October 1954. Happily, however, the four following charter members still survive: T. L. Condron; L. C. Fritch, past president and past secretary; E. C. Macy; and William Michel.

During the year there were a total of 46 deaths among the membership, as is recorded in the roster of deceased members at the end of this report.

Among those who died during the past year were two former presidents and Honorary Members of the Association—J. M. R. Fairbairn (president 1925–1926), and E. M. Hastings, Sr. (president 1939–1940). A memoir to Mr. Fairbairn appeared in Bulletin 517 for September–October 1954, while a memoir to Mr. Hastings appears in Bulletin 521 for February 1955. Others among the deceased who served the Association long and faithfully include W. C. Barnes, who was engineer of tests of the Rail committee; C. H. R. Howe, who had been a member of several committees since joining the Association in 1912, and who was chairman of Committee 27—Maintenance of Way Work Equipment, from 1942 to 1945; G. E. Martin, former chairman of Committee 13—Water, Oil and Sanitation Services; and C. D. Turley, former chairman of Committee 3—Ties, who died on January 27, 1955, just before the close of the Association's membership year on February 1.

ACTIVITIES OF COMMITTEES

Membership on Committees

Membership on Association committees reached another all-time high in 1954, with the prospect of a further increase in the year ahead under two new rules adopted by the Board during the year to spread further the advantages of membership among members and the railroads, while at the same time bring to committees increased knowledge and experience. One of the new rules increases from 60 to 70 the number of members permitted on a committee, while the second revises the former rule respecting retired members on committees to the effect that they no longer count against the total of 70 permitted on committees, or against the quota permitted on a committee from any railroad or other organization. Thus, it is possible for the actual membership of committees to exceed 70, although retired members are no longer permitted to vote on matters pertaining to official committee work.

On February 1, 1955, 1078 members (including 45 Members Emeritus) were serving on committees, occupying a total of 1213 places on these committees, since a number of members serve on two committees. This compares with 1035 members who occupied 1165 places on committees on the same date in 1954, and with 986 members who served in 1119 places on committees 2 years ago.

Again during the past year practically all committees carried "Guest" members on their rosters—members awaiting definite assignment to the committees with the roster changes last fall, but who were allowed to participate unofficially in committee work. In addition, an increasing number of "Visitors" were welcomed to meetings, including interested outsiders, retired members, Junior Members, and members of the Association generally, who for one reason or another could not be assigned to committees, but who wished to participate in specific meetings or the inspection trips made by committees.

Work of Committees

The work of committees during 1954, with overhauling of the Manual in 1953 out of the way, again followed the more normal pattern of preparing progress and information reports, and developing new Manual material. This is reflected in the accompanying table which classifies the material contained in committee reports for the past eight years.

CLASSIFICATION OF MATERIAL IN COMMITTEE REPORTS

(Figures shown indicate the number of Manual documents affected or new reports)

	1948	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*
Revisions of Manual with or without reapproval	58	37	24	20	19	257	14	24
Reapproval of Manual material without revisions	23	7	5	5	2	243	1	0
New Manual material	5	4	6	5	6	12	9	10
New Manual material—tentative	7	2	4	2	8	6	7	6
Information	29	35	49	57	43	49	59	53
Reports on research work ...	16	19	18	23	15	18	23	26
Reports on service tests	3	7	7	1	10	13	10	10
Statistical data	3	4	2	3	9	5	4	3
Analytical studies	8	14	7	2	2	5	3	2
Bibliographies	2	2	3	3	2	2	2	3
Brief reports of progress	16	20	13	8	16	11	17	16
	170	151	138	129	132	621	149	153

Committee Meetings

Slightly fewer committee meetings were held in 1954, primarily in the interest of economy, but an increasing number of committees desirably held their first, or reorganization, meeting prior to the convention in March in order to get an early start on their year's work. Altogether, the 23 standing and special committees of the Association held a total of 67 meetings of their full committees during the year ended March 1, 1955, many of which included inspection trips of one kind or another in the interest of their work. This total of 67 meetings, which included a number of luncheon meetings held during the annual meeting, compares with 76 meetings held in 1953, and 79 meetings held in 1952, a year in which a number of extra meetings were held in conjunction with the Centennial of Engineering. It also compares with 69 meetings held in 1951 and 50 during 1950. One committee held 5 meetings in 1954, 5 held 4 meetings, 10 held 3 meetings, 5 held 2 meetings, and 2 committees had only 1 meeting.

Of the 67 meetings, 37 were held at Chicago, 6 were held in St. Louis, Mo., 4 were held in New Orleans, La., 3 were held in Cincinnati, Ohio, 2 each were held at Washington, D. C., Cleveland, Ohio, and Pittsburgh, Pa., and 11 were held in as many different places.

With the beginning of the new Calendar Year 1955, there was much concern both among the officers of the Association and committees as to the possible effect on the location of committee meetings, and attendance thereat, of the restrictions on passes for business purposes (including travel to committee meetings) put into effect January 1, 1955, by a few eastern roads. Of a certainty, ways and means will be adopted to the end that the valuable work of the Association through its committees will not be impaired. In fact, one committee of the Association—24—Cooperative Relations with Universities, has adopted a plan for two meetings each year instead of the one held in recent years at Association headquarters, one of the meetings to be held at the headquarters of a railroad which has given more than ordinary attention to the recruiting and training of young graduate engineers, and the other on the campus of one of the colleges represented on the committee.

Key Position of Chairmen Recognized

There was no let-up in the effort of the Board of Direction and the secretary's office to cooperate with committees in the handling of their work and in bringing about a clear understanding of their assignments and of the rules governing committee procedure. However, in a modification of the procedure followed since 1949 of bringing all committee chairmen to Chicago in April to meet with members of the Board and the secretary's office, for, as it were, a review or refresher course, only the new committee chairmen were brought together in 1954—this meeting being held on April 26. This modified procedure was adopted in the interest of economy, and any disadvantage resulting from the standpoint of those committee chairmen not present at the meeting was offset as effectively as possible by means of correspondence and reference to the Information and Rules for the Guidance of Committees, and Style Standards, presented in the Outline of Work Pamphlet. Incidentally, to encourage frequent reference to the information, rules and standards in the pamphlet, and to make them more readily found by chairmen and others, the 1955 Outline of Work Pamphlet, issued late in December 1954, for the first time includes a detailed table of contents.

To recognize and honor committee chairmen for their interest and effort in behalf of the Association, the practice was continued of presenting each new committee chairman, as he assumed the chairmanship at the annual meeting in March, with an attractive gavel, with a polished brass band bearing his name, the committee number, and the years of his term of office. Likewise, the chairmen were the guests of the Association at a second Speakers' Table at the Annual Luncheon of the Association at the convention in March, and as the year closed, the officers of the Association were looking for still additional ways in which they might recognize and honor chairmen for their important service to the Association.

Committee on Convention Arrangements

While not counted among its technical committees, one of the very important committees of the Association is its Committee on Convention Arrangements, which plans for and executes or supervises all of the functions at annual meetings, except the program. Less known than the technical committees, both because it has chosen to keep in the background, and because its roster does not appear in any publication, this committee, nevertheless, renders a most significant, if not invaluable, service to the Association. In recognition of the great service by many members of this committee, the Board of Direction in 1954 created the degree of Honorary Member of the Arrangements Committee, which may, by committee action, be conferred on former members of the committee who, for a period of ten years or more, have rendered outstanding service to the committee. Immediately following the adoption by the Board of the rules relating to this new honorary degree—early in November 1954—the Arrangements Committee unanimously elected as its first Honorary Member, R. C. Bardwell, retired superintendent water service, Chesapeake and Ohio Railway.

Typical of the thoroughness with which this committee functions is the fact that in 1954 it completely revised its typewritten Manual of Practice, first formulated in 1953, and has now issued it in pocket size, loose-leaf form, with binder, containing 40 pages and a complete index.

PUBLICATIONS

The 7 Bulletins ending with the February 1955 issue contain 1255 pages of text matter and illustrations, exclusive of advertising, in addition to 41 trackwork plans, which were issued under separate cover as Part 2 of Bulletin 521 for February 1955. This compares with the 1138 pages for the 7 Bulletins ending with the February 1954 issue, and with the 1595 pages for the 7 Bulletins ending with the February 1953 issue. The substantially larger number of pages in the year ending with the February 1953 Bulletin reflects primarily the greater volume of reports in that year dealing with revision of the Manual, the year in which the Manual was completely overhauled and reprinted.

The committee reports published for presentation at the March 1955 annual meeting occupy 664 pages in Bulletins 518 to 521, incl., to which should be added the 322 pages of reports on research projects sponsored by AREA committees, or by groups in which AREA committees are interested, which appear in Bulletins 516 and 517 for June–July 1954, and September–October 1954, respectively.

Supplements to Manual and Portfolio of Trackwork Plans

The Annual Supplement to the Manual issued in 1954, incorporating all of the recommendations of committees affecting Manual material adopted at the 1954 annual meeting, included a total of 98 pages, 25 of which involved changes in the Tables of Contents of the various chapters. As a whole, this Supplement called for the removal of 79 pages from the Manual, leaving a net gain of 19 pages in the Manual as revised. No Supplement to the Manual was issued in 1953, all of the recommendations of committees, as adopted at the 1953 annual meeting, having been incorporated directly in the completely revised and reissued Manual put out late in that year.

The Annual Supplement to the Portfolio of Trackwork Plans issued in 1954 included 5 plans, 1 index sheet, and 1 Appendix sheet—a total of 7 sheets. That this number was not larger was because of a comprehensive review of all plans by Committee 5—Track, scheduled for and carried out in 1954, as reported in Bulletin 521, Parts 1 and 2, which contemplates the withdrawal of 11 plans and the revision of 85 others, affecting about 70 percent of the Portfolio, looking to distribution of the revised plans in the 1955 Supplement. In addition, major revisions will be proposed at the 1955 annual meeting in the specifications included in Appendix A of the Portfolio.

Sale of Publications

In the Calendar Year 1954, the Association again made widespread distribution of its publications over and above those copies going to its own large membership. This distribution included approximately 32,400 copies, 28,300 of which were sold from the secretary's office to, among others, the American railroads, colleges and universities, students, government agencies, engineers in industry generally, and railroad men in foreign countries. The remaining 4100 copies, including approximately 2500 reprints of research reports and nearly 1000 copies of previous reports of Committee 24—Cooperative Relations with Universities, were sent out free by the AAR research staff and the secretary's office. In addition, by authority of the Board of Direction, 370 copies of the 43-page booklet entitled "Railroad Location and Construction Procedures, from the School of Experience", by J. A. Given, were sent free to the deans and civil engineering professors of all of the accredited engineering colleges of the United States and Canada.

Especially significant among the publication sales was that of 812 copies of the recently reprinted Manual, either as fillers, without binders, or complete with 2 binders. This sale compares with average annual Manual sales of about 200 copies over the past 8 years.

Following is a tabulation of the publication sales made in 1954:

Sales of Association Publications—1954

Specifications (Bridge)	2,006
Manual chapters	1,400
Manual specifications and partial chapters	1,107
Manual specifications, large orders (more than 100)	2,950
Bulletins	1,402
Bulletin reprints	307
Special reprints in large orders (100 or more)	13,750
Proceedings	144
Consolidated Proceedings indexes	420
Revisions to Manual	478
Manuals (complete) and separate fillers	812
Revisions to Portfolio of Trackwork Plans	870
Complete Portfolios of Trackwork Plans	81
Individual track plans	1,536
Instructions for Mixing and Placing Concrete	104
Instructions for Care and Operation of Maintenance of Way Work Equipment	98
Federal Valuation of Railroads	17
Achievement of Grade Crossing Protection	16
J. A. Given booklets	714
	28,302

Large as was this distribution of publications in 1954, it was again restricted by the Association's refusal to fill many foreign orders which did not have the sanction of the Office of International Trade at Washington, D. C.

FINANCES

Examination of the Report of the Treasurer, Financial Statement and Statement of Cash Receipts and Disbursements for the calendar year 1954, all of which are presented herewith, indicate that the Association is in a sound and favorable financial condition. Receipts during the year exceeded Disbursements by $17,745.96. A comparison of Receipts and Disbursements for the past two years is presented below:

	1953	*1954*
Receipts	$73,033.07	$85,748.99
Disbursements	82,067.86	68,003.03
	$—9,034.79	$17,745.96

Reviewing the situation briefly, receipts in 1954 were some $12,700 greater than in 1953 This increase was due to the unprecedented sale of the new Manual, issued in November 1953, and the resultant large revenue from sales in 1954. The balance of the items under Receipts in the Financial Statement, with one exceptions—Research Report Refunds—are slightly larger than in 1953, totaling approximately $1100, but these increases were offset in total by a decrease in the Research Report Refunds, which was $1100 under the 1953 receipts for this item.

Like the Receipts, the Disbursements for the years 1953 and 1954 do not represent a fair comparison, again due to the Manual, as the bulk of the cost of reprinting it, in the amount of $20,372, was paid in 1953, compared to an expenditure for the Manual in 1954 of $5,984, a differential of $14,368. Total Disbursements in 1953 were $82,067.86, and in 1954, $68,003.03, a difference of $14,064.83. This figure compared to the Manual differential of $14,368 in the two years indicates that even with an increase in Salary disbursements, due to one additional employee in 1954, and in Printing disbursements, due to an increase in the unit cost of printing during the year, economies were effected so that the balance of the disbursement items were lower in 1954 than in 1953.

Thus, with excess Receipts over Disbursements of $17,745.96 in 1954, the General Balance Sheet shows liquid assets for 1954 of, Investments $131,241.39, Cash $3,831.47, and comparable items for 1953 of $110,607.69 and $6,664.15. Total assets of the Association for 1954 were $145,194.08, and for 1953 $140,407.19. The relatively high total assets in 1953, with smaller liquid assets, was due to the inclusion, as inventory, on a conservative cash basis, of $15,880, representing the value of the reprinted Manual fillers in stock, not used as replacements for Members' Manuals, and a supply of Manual binders. The Association's total assets, shown as $145,194.08 for 1954, include an inventory of only $5,406 for Manuals, which will eventually be converted into cash, indicating that the 1953 issue of the Manual was a sound investment, and that despite the 1400 copies distributed gratis to member holders of previous editions of the Manual, will be the first Manual printing that has paid for itself.

Comparison of Receipts and Disbursements for a 20-Year Period

	Receipts	*Disbursements*	*Net Gain*
1935	$29,001.00	$30,110.00	$1,109.00*
1936	28,643.00	34,662.00	6,019.00*
1937	36,523.00	32,200.00	4,323.00

	Receipts	Disbursements	Net Gain
1938	28,422.00	23,394.00	5,028.00
1939	28,189.00	23,847.00	4,342.00
1940	28,272.00	26,451.00	1,821.00
1941	32,433.00	29,384.00	3,049.00
1942	31,500.00	26,692.00	4,808.00
1943	28,736.00	23,809.00	4,927.00
1944	30,492.00	26,534.00	3,958.00
1945	32,305.00	29,305.00	3,000.00
1946	28,836.00	34,583.00	5,747.00*
1947	46,993.00	46,989.00	4.00
1948	57,741.00	53,062.00	4,679.00
1949	62,081.00	57,075.00	5,005.00
1950	59,752.00	51,795.00	7,957.00
1951	69,045.00	62,369.00	6,676.00
1952	77,514.00	76,964.00**	550.00
1953	73,033.07	82,067.86**	9,034.79*
1954	85,748.99	68,003.03**	17,745.96

* Deficit.
** Manual revision and reprinting 1952, $4908.09; 1953, $20,572.58; 1954, $936.54.

RESEARCH WORK

The research activities of the Association, sponsored by its committees and carried out by the research staff of the Engineering Division, AAR, and the facilities of several colleges and research organizations, continued at a high and productive level in 1954, but was not as extensive as had been planned and hoped for. The secretary's 1953 report shows that, at the time that report was written, $390,307 had been appropriated for Engineering Division research work and research office expense in 1954, but that a cut of 10 percent was in prospect in view of reduced railway revenues in the latter months of 1953, and lower anticipated level of earnings in at least the first half of 1954. Influenced by these conditions, actual expenditures for the Division's research program in 1954 were held to $351,307, which compared with expenditures of $364,100 in 1953, and amounts in earlier years as shown in one of the accompanying tables.

Again in 1955, for the same reasons prevailing in 1954, the research work of the Association will not be all that was tentatively programmed and hoped for, as a desired budget of $429,250 set up in the fall of 1954 was necessarily reduced to $351,653 in its approved form—practically the same as that in 1954. Thus, several new projects originally proposed by committees for 1954 will necessarily be held over for another year, and several new projects which committees had hoped to get underway in 1955 will be deferred.

The projects to be continued or initiated in the year ahead, and the amount appropriated for each, compared with 1954 and 1953, are shown in the second accompanying table:

Total Allotments for Research Work, Engineering Division, AAR, 1938–1955

1938	$ 78,158	1947	$234,428
1939	77,650	1948	291,840
1940	69,250	1949	372,457
1941	95,150	1950	294,045
1942	87,932	1951	354,770
1943	98,445	1952	381,400
1944	109,050	1953	364,100
1945	138,110	1954 (as modified)	351,307
1946	159,510	1955	351,653

Engineering Division Allotments for Research 1953–1955

	1953 Budget	1954 Modified Budget	1955 Budget
Committee on Rail			
Transverse Fissure Investigation	$ 5,500	$ 5,590	$ 5,600
Shelly Spots Investigation	14,500	9,400	9,000
Rail Failure Statistics	8,600	8,860	8,950
Service Tests of Joint Bars	4,000	2,825	2,825
Rolling-Load Tests of Joint Bars	11,500	12,225	11,725
Rail Design Investigation	9,300	12,300	13,000
Rail End Batter	0	4,000	4,500
Tests with 78 ft Rail	5,000	3,500	3,500
Total	$ 58,400	$ 58,700	$ 59,100
Committee on Track			
Tie Plates, Stresses	$ 6,000	$ 5,300	$ 5,300
Bolt Tension and Joint Lubrication	4,000	3,920	3,500
Corrosion from Brine Drippings	10,000	11,250	11,000
Stresses in Manganese Frogs	6,000	4,500	3,400
Tests of Rail Anchorage	5,000	4,500	400
Tie Plate Fastenings	8,000	13,600	13,900
Welding Carbon Steel Frogs and Switches	5,000	7,100	6.600
Total	$ 44,000	$ 50,170	$ 44,100
Relation Between Track and Equipment			
*Jack Knifing of Diesel Locomotives	0	0	$ 10,000
Relation Wheel Load to Wheel Diameter	5,000	5,225	5,200
Relation Wheel-Track Curvature	10,000	2,225	0
Clearance Requirements	0	8,000	0
Total	$ 15,000	$ 15,450	$ 15,200
Committee on Roadway and Ballast			
Roadbed Stabilization	$ 24,000	$ 24,000	$ 24,000
Ballast Tests	6,300	8,000	8,000
Vegetation Control by Chemicals	12,500	13,000	13,000
Total	$ 42,800	$ 45,000	$ 45,000
Committee on Ties			
Wear and Splitting of Ties	$ 10,000	$ 10,000	$ 10,000
Total	$ 10,000	$ 10,000	$ 10,000
Structural Projects			
Bridge Impact Investigation	$ 78,000	$ 72,787	$ 70,140
Stress in Bridge Frames	8,000	2,750	10,000
Riveted and Bolted Structural Joints	10,000	8,000	8,000
Column Research Council	3,000	1,000	1,000
Steel Structures Painting Council	10,000	8,000	8,000
Timber Stringer Tests	5,000	5,500	5,500
Performance for Fire Retardants	5,000	5,260	5,260
Concrete Deterioration	10,000	9,200	9,200
Reinforced Concrete Research Council	5,000	4,000	4,000
Strength of Timber Bolted Joints	3,000	2,800	2,800

	1953 Budget	1954 Modified Budget	1955 Budget
Tests of Membrane Waterproofing Material	5,400	6,172	6,200
Tests of Bituminous Materials	8,100	9,208	9,000
Wind Loads on Buildings	1,000	1,000	1,000
Total	$151,500	$135,677	$140,100
Administration			
Research Office	$ 34,900	$ 36,310	$ 38,153
Research Publications Cost	7,500	**	**
Total	$ 42,400	$ 36,310	$ 38,153
Grand Total	$364,100	$351,307	$351,653

* New project in 1955.
** Included in various projects.

What's Ahead

Crowning the achievements of the past year as set forth in the foregoing, the Association, even as this report is being written, is completing plans for another successful convention, March 15–17, which, indeed, may well exceed in attendance those of recent years under the influence of somewhat improved, or stabilized, economic conditions, and the impact of the large exhibit to be held in conjunction with the convention by the National Railway Appliances Association.

The future of the Association, as in the past, depends upon the continued joint interest and support of both its individual members and the railroads which they represent. Individual members must be willing to contribute of their off-the-job time and thought to Association work, often at considerable sacrifice, to bring into being the many benefits that result to themselves and the railroad industry. The railroads, at the same time, in recognition of the vast reservoir of knowledge which is built up in their behalf by the Association, must encourage their men in Association work, allow them a reasonable amount of on-the-job time and assistance to carry it out, permit them to attend committee meetings insofar as possible, and be willing to defray reasonable direct expenses in connection therewith. In other words, both members and their railroads benefit—both must assume responsibilities. If they will continue to do this in the future as they have so enthusiastically in the past, even though to do so may become a bit more exacting and cost some a little more as conditions may change, the benefits that accrue from Association activities will continue and multiply to members individually and to their respective railroads.

Respectfully submitted,

Neal D. Howard,
Secretary.

Deceased Members

C. W. Baldridge
Retired Assistant Engineer, Atchison, Topeka & Santa Fe Railway, 7413 Clyde Ave., Chicago, 49, Ill.

W. C. Barnes
Retired Engineer of Tests, Association of American Railroads, 367 Foss Ct., Lake Bluff, Ill.

W. C. Barrett
Retired Chief of Personnel, Lehigh Valley Railroad, 123 E. Market St., Bethlehem, Pa.

G. A. Belden
Assistant Chief Engineer, Central of Georgia Railway, Savannah, Ga.

C. E. Bishop
Assistant Engineer, Missouri Pacific Railroad, Osawatomie, Kans.

J. D. Buchanan
Engineer in Charge, Pennsylvania Railroad, Chicago, 6, Ill.

W. S. Burnett
Retired Chief Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway, 624 F St., Centralia, Wash.

J. P. Canty
Retired Assistant to Engineer Maintenance of Way, Boston & Maine Railroad, 40 Prospect St., Melrose, Mass.

E. A. Craft
Executive Vice President, Southern Pacific Lines, Houston, 1, Tex.

W. O. Cudworth
Retired Engineer Maintenance of Way, Canadian Pacific Railway, Sharbot Lake, Ont.

C. E. Dare
Retired Supervisor of Track, Richmond, Fredericksburg & Potomac Railroad, 459 Willets, Birmingham, Mich.

A. L. Davis
Retired Principal Assistant Engineer, Illinois Central Railroad, 1225 Thompson Place, Daytona Beach, Fla.

C. G. Delo
Retired Real Estate and Tax Agent, Chicago Great Western Railway, 1627 Pine Road, Homewood, Ill.

Joshua D'Esposito
Consulting Engineer, 2744 Ridge Ave., Evanston, Ill.

H. H. Edgerton
607 Lincoln Ave., St. Paul, 2, Minn.

J. M. R. Fairbairn
Retired Chief Engineer, Canadian Pacific Railway, 424 Wood Ave., Westmont, Que.

Stephen Francescon
Assistant Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, Chicago, 6, Ill.

C. B. Harveson
Chief Engineer Maintenance, Baltimore & Ohio Railroad, Baltimore, 1, Md.

E. M. Hastings
Retired Chief Engineer, Richmond, Frederickburg & Potomac Railroad, 515 North Blvd., Richmond, 20, Va.

W. K. Hatt
Professor Emeritus of Civil Engineering, Purdue University, Ann Arbor, Mich.

H. C. HEINLEN
804 43rd St., Los Alamos, N. M.

M. G. HILPERT
Consulting Engineer, Bethlehem Steel Company, 93 W. Church St., Bethlehem, Pa.

C. H. R. HOWE
Retired Cost Engineer, Chesapeake & Ohio Railway, 1203 W. 42nd St., Richmond, 25, Va.

A. C. JACKSON
Assistant General Passenger Agent, Missouri Pacific Railroad, Houston, 1, Tex.

J. R. KEIG
2440 Harrison, Beaumont, Tex.

G. A. KNAPP
Special Engineer, Joint Railroad Special Committee, 503 Houston Bank & Trust Bldg., Houston, Tex.

J. F. LEONARD
Retired Engineer Bridges and Buildings, Pennsylvania Railroad, McKown St., Glen Osbourne, Sewickley, Pa.

C. G. LUNDAY
Vice President, Louisiana & Arkansas Railway, Shreveport, La.

G. E. MARTIN
Superintendent Water Service, Illinois Central Railroad, Chicago, 5, Ill.

R. J. MIDDLETON
Retired Chief Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad, 4515 Fourth Ave., N. E., Seattle, Wash.

R. E. MILLER
Chief Engineer, Frog & Switch Department, Bethlehem Steel Company, Steelton, Pa.

W. L. MORSE
Retired Special Assistant Engineer, New York Central Railroad, Jefferson Roadway Gables, Buzzards Bay, Mass.

F. L. NICHOLSON
Retired Chief Engineer, Norfolk Southern Railway, 512 Graydon Park, Norfolk, 7, Va.

W. F. RENCH
Civil Engineer, 5123 Warrington Ave., Philadelphia, Pa.

R. S. SABINS
Assistant Engineer Maintenance of Way, Central Vermont Railway, St. Albans, Vt.

A. G. SHAVER
Consulting Signal Engineer, 434 North Hazel St., Danville, Ill.

G. J. SHEPPARD
Division Engineer, Atlantic Coast Line Railroad, Wilmington, N. C.

S. R. SPROLES
Engineer Standards and Research, Gulf, Mobile & Ohio Railroad, Mobile, 5, Ala.

H. E. STEVENS
Retired Vice President, Northern Pacific Railway, 727 Linwood Ave., St. Paul, 5, Minn.

F. L. STINER
Supervisor of Track, Illinois Central Railroad, Waterloo, Ia.

J. A. STOCKER
Retired Consulting Engineer, New York Central System, 916A, Park View Apts., Collingswood, 6, N. J.

George Story
Retired Assistant Engineer, Southern Railway System, Cincinnati, 2, Ohio

C. D. Turley
Engineer of Ties and Treatment, Illinois Central Railroad, Chicago, 5, Ill.

C. W. Van Nort
Engineer Maintenance of Way, Pennsylvania Railroad, Pittsburgh, 22, Pa.

J. L. Vogel
Retired Engineer of Structures, Delaware, Lackawanna & Western Railroad, 46 Virginia Ave., Manasquan, N. J.

J. E. Wheeler
Division Engineer, Southern Pacific Company, San Francisco, 5, Calif.

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1954

Balance on hand January 1, 1954			$117,351.90

RECEIPTS

Membership Account			
Entrance Fees	$ 2,390.00		
Dues	41,988.70	$44,378.70	
Sale of Publications			
Proceedings	1,288.21		
Bulletins	2,048.35		
Manuals	17,759.08		
Specifications	2,428.54		
Track Plans	1,490.06		
Research Reports—Refund	6,677.83	$31,692.07	
Advertising			
Publications		$ 5,783.20	
Interest Account			
Interest on Investments	$ 3,461.34		
Less interest paid on bonds purchased	254.55	$ 3,206.79	
Miscellaneous		$ 611.85	
Profit on sale of bonds		76.38	
Total		$85,748.99	

DISBURSEMENTS

Salaries	$20,959.31		
Proceedings	14,132.38		
Bulletins	11,377.56		
Stationery and printing	3,559.57		
Rent, light, etc.	1,140.00		
Supplies	264.68		
Postage	1,635.78		
Audit	400.00		
Pensions	1,500.00		
Social security and unemployment taxes	400.80		
Manual	5,984.69		
Track plans	1,130.50		
Committee and officers expenses	442.99		
Annual meeting expenses	1,774.84		
News letter	2,694.80		
Miscellaneous	605.13		
Total		$68,003.03	
Excess of Receipts over Disbursements		17,745.96	
Balance on hand December 31, 1954			$135,097.86

REPORT OF THE TREASURER

To the Members:

Balance on hand January 1, 1954		$117,351.90
Receipts during 1954	$ 85,672.61	
Paid out on audited vouchers	68,003.03	
Excess of Receipts over Disbursements	$ 17,669.58	
Profit from sale of bonds	76.38	17,745.96
Balance on hand December 31, 1954		$135,097.86
Consisting of bonds at cost	$131,241.39	
Cash in Northern Trust Company Bank	3,831.47	
Petty cash	25.00	$135,097.86

We have made an examination of the accounts of the American Railway Engineering Association for the year ending December 31, 1954, and find them to be in accordance with the foregoing statement.

C. A. Bick,
P. D. Mitchell,
Auditors.

GENERAL BALANCE SHEET

Assets	*1954*	*1953*
Due from members	$ 21.00	$ 126.50
Due from sale of publications	133.95	44.69
Due from sale of advertising	658.40	687.40
Due from prepaid postage	19.23	
Furniture and fixtures	1,220.30	1,186.00
Inventory of publications (estimated)	500.00	500.00
Inventory of Manuals	5,406.40	15,880.00
Inventory of track plans	1,681.00	2,004.80
Inventory of binders, index and chapters	20.73	1,650.00
Inventory of paper stock	142.80	642.60
Investments (cost)	131,241.39	110,607.69
Interest accrued on investments	292.41	388.36
Cash in Northern Trust Company Bank	3,831.47	6,664.15
Petty Cash	25.00	25.00
Total	$145,194.08	$140,407.19
Liabilities		
Members dues paid in advance	$ 476.80	$ 494.80
Surplus	144,717.28	139,912.39
Total	$145,194.08	$140,407.19

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS YEAR 1954

Cash in Bank, January 1, 1954			$ 6,664.15
Receipts			
From members, sale of publications, interest, etc.		$ 85,672.61	
Sale of bonds		33,724.00	119,396.61
			$126,060.76
Disbursements			
Audited vouchers		$ 68,003.03	
Government bonds purchased	$54,480.81		
Less interest paid on bonds	254.55	54,226.26	$122,229.29
Cash in Bank, December 31, 1954			$ 3,831.47

American Railway Engineering Association

CONSTITUTION

Revised to October 30, 1950

Article I

NAME, OBJECT AND LOCATION

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Standing and Special Committees.

(b) Meeting for the presentation and discussion of papers, and for action on the recommendations of committees.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions adopted by the Association shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Ill.

Article II

MEMBERSHIP

1. Classes

The membership of this Association shall be divided into five classes: Members, Life Members, Honorary Members, Associates and Junior Members.

2. Qualifications

A. GENERAL

(a) An applicant to be eligible for membership in any class other than that of Junior Member shall be not less than 25 years of age.

(b) To be eligible for membership in any class, or for retention of membership as a Member, an Associate or a Junior Member, a person shall not be engaged directly or primarily in the sale to the railways of appliances, supplies, patents or patented services.

(c) The right to membership shall not be terminated by retirement from active service.

(d) In determining the eligibility for membership in any class, graduation in engineering from a school of recognized standing shall be considered as equivalent to three years of active practice, and satisfactory completion of each year of work in such school, without graduation, shall be considered as equivalent to one-half year of active practice.

(e) In determining the eligibility for Member under Section B (a) of this Article, each year of practical experience in engineering, or in science related thereto, prior to employment on a railway, if such experience were of the same specialized character as the current work of the applicant, shall be considered as equivalent to one year of railway service.

B. Member

A Member shall be:

(a) An engineer or officer in the service of a railway corporation that is a common carrier, who has had not less than five years' experience in the location, construction, operation or maintenance of railways.

(b) A dean, professor, assistant professor, or equivalent in engineering in a university or college of recognized standing, or an instructor or equivalent in such university or college, who, with an engineering degree, has had at least two years' experience in teaching engineering.

(c) An engineer or member of a public board, commission or other official agency who, in the discharge of his regular duties, deals with railway problems.

(d) An editor of a trade or technical magazine who, in the discharge of his regular duties, deals with railway problems, and who has had the equivalent of five years' engineering or railway experience.

(e) A consulting engineer, engaged in private practice, or an engineer in his employ or in the employ of a consulting engineering organization, who has had the equivalent of five years' engineering experience.

C. Life Member

A Life Member shall be a Member or an Associate who has paid dues for 35 years, or who has been retired under a recognized retirement plan and has paid dues for not less than 25 years.

D. Honorary Member

(a) An Honorary Member shall be a person of acknowledged eminence in railway engineering or management.

(b) The number of Honorary Members shall be limited to ten.

E. Associate

An Associate shall be:

(a) An engineer of a railway which is essentially an adjunct of an industry, or which is used primarily to transport the products and materials of an industry to and from a railway which is a common carrier.

(b) A person qualified by training and experience to cooperate with Members in the object of this Association, but who is not qualified to become a Member.

F. Junior Member

(a) A Junior Member shall be not less than 21 years of age and shall be an engineering employee of a railway corporation who has had not less than three years of experience in the location, construction, operation or maintenance of railways.

(b) His membership in this classification in the Association shall terminate at the end of the calendar year in which he becomes 30 years of age.

(c) He may make application for membership other than as a Junior Member at any time when he becomes eligible to do so.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership, any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members, and Life Members who were formerly Members, shall have all the rights and privileges of the Association. Life Members who were formerly Associates shall continue to have all the rights and privileges of Associates.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates and Junior Members shall have all the rights and privileges of the Association except those of voting and holding elective office.

Article III

ADMISSION, RESIGNATION, EXPULSION AND REINSTATEMENT

1. Charter Membership

The Charter Membership of this Association consists of all persons elected to membership before March 15, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form provided by the Board of Direction. In the event that Junior Membership is desired, the applicant shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of these Members shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's qualifications for membership.

(c) If an applicant is not personally known to as many as three Members of this Association, the names of well-known persons engaged in railway or allied professional work to whom he is personally known shall be substituted, as necessary, to provide a total of at least three references. Each of these persons shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant, with an opinion of the applicant's qualifications for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with the required information, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible, and the admission of the applicant shall be canvassed by ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

(d) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (c) of this Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

An applicant for any class of membership in this Association shall declare his willingness to abide by the Constitution of the Association in his application for membership.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fulfilled.

7. Expulsion

Charges of misconduct on the part of anyone holding membership in this Association, if in writing and signed by ten or more Members, may be submitted to the Board of Direction for examination and action. If, in the opinion of the Board action is warranted, the person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be required for expulsion.

8. Reinstatement

(a) A person having been a Member, an Associate or a Junior Member of this Association and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member, an Associate or a Junior Member of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

Article IV

Dues

1. Entrance Fee

(a) An entrance fee of $10 shall be payable to the Association with each application for membership other than Junior Membership. This sum shall be returned to an applicant not elected.

(b) No entrance fee shall be required for Junior Membership, except that a Junior Member, in transferring to another class of membership, shall pay the entrance fee prescribed for other classes of Membership.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be $15.

(b) The annual dues for each Junior Member shall be $7.50.

(c) Life Members and Honorary Members shall be exempt from the payment of dues. Life Members desiring to continue to receive the Bulletins and Proceedings of the Association may do so by paying a subscription fee prescribed by the Board of Direction.

3. Arrears

A person whose dues are not paid before April 1 of the current year shall be notified by the Secretary. If the dues are still unpaid on July 1, further notice shall be given, informing the person that he is not in good standing in the Association. If the dues remain unpaid by October 1, the person shall be notified that he will no longer receive the publications of the Association. If the dues are not paid by December 31, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, Associate or Junior Member who, for good reason, is unable to pay them.

Article V

Officers

1. Officers

(a) The officers of the Association shall be a President, two Vice Presidents, twelve Directors, a Secretary and a Treasurer.

(b) The President, the Vice Presidents and the Directors, together with the two latest living Past Presidents continuing to be Members, shall constitute the Board of Direction, in which the government of the Association shall be vested; they shall act as the trustees and have the custody of all property belonging to the Association. The President, the Vice Presidents and the Directors shall be Members.

(c) The Secretary and the Treasurer shall be appointed by the Board of Direction.

2. Term of Office

The term of office of the President shall be one year, of the Vice Presidents two years and of the Directors three years. The term of each shall begin at the close of the annual convention at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position at the pleasure of the Board of Direction.

3. Officers Elected Annully

(a) There shall be elected at each annual convention a President, one Vice President and four Directors.

(b) The candidates for President and for Vice President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election, except as provided for in Section 5 (e) of this Article. Vice Presidents and Directors shall be ineligible for re-election to the same office, except as provided for in Section 5 (e) of this Article, until, at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) If a vacancy should occur in the office of President, as set forth in Section 6 of this Article, the senior Vice President shall immediately and automatically become President for the unexpired term.

(b) If a vacancy should occur in the office of the senior Vice President, due to advancement under Section 5 (a) of this Article, or for reasons set forth in Section 6 of this Article, the junior Vice President shall automatically become senior Vice President for the unexpired term.

(c) If a vacancy should occur in the office of the junior Vice President, due to advancement under Section 5 (b) of this Article, or for reasons set forth in Section 6 of this Article, the Board of Direction shall by the affirmative vote of two-thirds of its entire membership, select a junior Vice President from the members or past members of the Board of Direction.

(d) A vacancy in the office of Director, due to advancement of a Director to junior Vice President under Section 5 (c) of this Article, or for reasons set forth in Section 6 of this Article, shall be filled by the Board of Direction by the affirmative vote of two-thirds of its entire membership.

(e) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided, however, that anyone selected to fill a vacancy as Director shall be eligible for election to that office, excepting that such appointee filling out an unexpired term of two years or more shall be considered as coming within the provisions of Section 4 of this Article.

6. Vacation of Office

(a) In the event of the death of an elected officer, or his resignation from office, or if he should cease to be a Member of the Association as provided in Section 2 (B), Article II; Section 6 or 7, Article III; or Section 3, Article IV, the office shall be considered as vacated.

(b) In the event of the disability of an officer or neglect in the performance of duty by an officer, the Board of Direction, by the affirmative vote of two-thirds of its entire membership shall have the power to declare the office vacant.

Article VI

Nomination and Election of Officers

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not Past Presidents shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past President who is a member of the committee shall be the chairman of the committee. In the absence of the senior Past President from a meeting of the committee the Past President next in seniority present shall act as chairman.

2. Method of Nominating

(a) Prior to December 1 of each year the chairman shall call a meeting of the committee at a convenient place, at which nominees for the several elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee*	*Number of Candidates to be elected at the Annual Election of Officers*
President	1	1
Vice President	1	1
Directors	8	4
Nominating Committee	10	5

(b) The chairman of the Nominating Committee shall send the names of the nominees to the President and Secretary not later than December 15 of the same year, and the Secretary shall report the names of these nominees to the members of the Association not later than January 1 following.

(c) At any time between January 1 and February 1 any ten or more Members may send to the Secretary additional nominations for any elective office for the ensuing year signed by such Members.

(d) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, his name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than thirty days prior to each annual convention, the Secretary shall issue a ballot to each voting Member of record who has paid his dues to or beyond December 31 of the previous year, listing the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate his record of membership and activities in this Association.

4. Substitution of Names

Members may remove names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw his ballot, and cast another, at any time before the polls close.

(c) Ballots received in unendorsed envelopes, or from persons not qualified to vote. shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at 12 o'clock noon on the second day of the annual convention, and the ballots shall be counted by tellers appointed by the presiding officer.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the annual convention shall elect the officer by ballot from the candidates so tied.

(c) The presiding officer shall announce at the convention the names of the officers elected in accordance with this Article.

Article VII

Management

1. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and, by virtue of his office, shall be a member of all committees, except the Nominating Committee.

2. Vice Presidents

The Vice Presidents, in order of seniority, shall preside at meetings in the absence of the President.

3. Treasurer

The Treasurer shall pay all bills of the Association when properly certified by the Secretary and approved by the Finance Committee. He shall make an annual report as to the financial condition of the Association and such other reports as may be called for by the Board of Direction.

4. Secretary

The Secretary, under the direction of the President and Board of Direction, shall be the Executive Officer of the Association and shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and record the proceedings thereof. The Secretary shall see that all money due the Association is collected, is credited to the proper accounts, and is deposited in the designated depository of the Association, with receipt to the Treasurer therefor. He shall personally certify to the accuracy of all bills and vouchers on which money is to be paid. He shall invest all funds of the Association not needed for current disbursements, as shall be recommended by the Finance Committee and approved by the Board of Direction, with notification to the Treasurer of such investments. The Secretary shall conduct the correspondence of the Association, make an annual report to the Association, and perform such other duties as the Board of Direction may prescribe.

5. Auditing of Accounts

The financial accounts of the Association shall be audited annually by an accountant or accountants approved by and under the direction of the Finance Committee.

6. Board of Direction

(a) The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided for in the Constitution.

(b) The Board of Direction shall meet within thirty days after each annual convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(c) Seven members of the Board of Direction shall constitute a quorum.

(d) At the first meeting of the Board of Direction after the annual convention, the following committees, each consisting of not less than three members, shall be appointed by the President from the Board of Direction, and they shall report to and perform their duties under the supervision of the Board of Direction.

Finance
Publications
Outline of Work of Committees
Personnel of Committees
Membership
Manual

Other special committees may be appointed by the President at his discretion.

7. Duties of the Committees of the Board of Direction

(a) Finance Committee

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of funds and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(b) Publication Committee

The Publication Committee shall have general supervision over the publications of the Association. The Publication Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(c) Committee on Outline of Work of Committees

The Committee on Outline of Work of Committees shall review and pass upon the recommendations of standing and special committees for subjects to be investigated, considered and reported on by these committees during the ensuing year, and shall report thereon to the Board of Direction for its approval.

(d) Committee on Personnel of Committees

The Committee on Personnel of Committees shall review and pass upon applications of members for appointment to standing and special committees. It also shall appoint the chairman and vice chairman of such committees and make a report thereon to the Board of Direction for its approval.

(e) Membership Committee

The Membership Committee shall make investigation of applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(f) Manual Committee

The Manual Committee, with the assistance of the Publications Committee, shall have general supervision over the Manual.

8. Standing Committees

The Board of Direction may appoint standing committees to investigate, consider and report upon questions pertaining to railway location, construction, operation and maintenance.

9. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

10. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

11. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual convention of the Association shall be deemed to be the act of the Association.

Article VIII

Meetings

1. Annual Convention

(a) The Annual Convention of the Association shall be held in the City of Chicago, Ill., or in such other city as may be determined by the affirmative vote of two-thirds of the entire membership of the Board of Direction. The convention shall open on the second Tuesday in the month of March, or on the third Tuesday if the month of March has five Tuesdays, excepting that some other opening day in March may be designated by the affirmative vote of two-thirds of the entire membership of the Board of Direction.

(b) The Secretary shall notify all members of the Association of the time and place of the annual convention at least 30 days in advance thereof.

(c) The order of business at the annual convention of the Association shall be:

Reading of the minutes of the last meeting
Address of the President
Reports of the Secretary and the Treasurer
Reports of committees
Unfinished business
New business
Installation of officers
Adjournment

(d) This order of business may be changed by a majority vote of Members present.

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

(f) Discussions shall be limited to Members and to those others invited by the presiding officer to speak.

2. Special Meetings

Special meetings of the Associations may be called by the Board of Directions on its own initiative, and may be so called by the Board of Direction upon written request of 100 Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten days in advance of the proposed date of such meeting and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five Members shall constitute a quorum at all meetings of the Association.

Article IX

Amendment

1. Amendment

Proposed amendment of this Constitution shall be made in writing, shall be signed by not less than ten Members, and shall be acted upon in the following manner:

The amendment shall be presented to the Secretary, who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes, the matter shall be submitted to the Association by letter ballot.

Sixty days after the date of issue of the letter ballot, the Board of Direction shall canvass the ballots which have been received, and if two-thirds of such ballots are in the affirmative the amendment shall be declared adopted and shall become effective immediately. The result of the letter ballot shall be announced to members of the Association.

Information and Rules for the Guidance of Committees

The following information and rules for the guidance of committees are designed to obtain the maximum benefits from the efforts of the members who make up the personnel of such committees. They are designed to effect a continuity of effort in committee work throughout the entire year, under a plan whereby the personnel of the committees and their respective outlines of work are set up and made public on or before the beginning of the calendar year, thus enabling the work to be continued without interruption, although the new personnel and subject assignments do not become officially effective until the beginning of the "Association Year," which starts with the close of the annual meeting.

The rules also take into account the fact that the publication of the committee reports must be spread out over a period of four months (November through February), to facilitate printing and to give members of the Association a reasonable length of time in which to study such reports in advance of the annual meeting.

SUBJECT ASSIGNMENTS

Reassigned Annually

The outline of work of each committee shall be reviewed annually. To this end, each committee shall review suggestions for new subjects submitted by the members thereof, or by others, and such suggestions as receive the approval of the committee shall be submitted by the committee chairman to the secretary of the Association not later than October 1, together with the committee's recommendations covering the withdrawal or continuation of current assignments.

The recommendations received from the various committees shall be assembled and forwarded to the Board Committee on Outline of Work, which shall have the responsibility of authorizing the subject assignments to the various committees. Deviation from assignments thus authorized may be made during the course of the year only upon the authority of the Board Committee on Outline of Work.

COMMITTEE PERSONNEL

Reorganized Annually

The personnel of each committee shall be reorganized annually. It is desirable that 10 percent of the membership be changed each year. Members who do not attend meetings of the committee, who do not render service by correspondence, or who do not return letter ballots will be dropped. To this end the chairman of the committee shall submit to the secretary of the Association not later than October 1 the names of members whom he recommends be dropped because of delinquence in service to the committee, as well as a list of the names of members of the Association whom he recommends for appointment to the committee.

The recommendations received from the various committees shall be assembled and forwarded to the Board Committee on Personnel, which has the duty of appointing the committee personnel.

No additions to the personnel of committees will be made during the year following the official closing of committee rosters—October 1, except as provided for in the rules applying to "Guests."

Members who desire appointment to a committee should make application through the chairman or the secretary on the prescribed form.

(Revised November 5, 1954).

Chairmen, Vice Chairmen and Subcommittee Chairmen

Chairmen, vice chairmen and subcommittee chairmen must hold the grade of Member in the Association, except that any Associates currently acting as subcommittee chairmen may continue to hold such office until succeeded by a Member.

The terms of chairmen and vice chairmen shall be three years in each position. Chairmen completing their three-year term shall recommend to the Board Committee on Personnel nominees for the chairmanship and vice chairmanship, with assurance of acceptance from such nominees if appointed by the Board Committee. The term of office of subcommittee chairmen may be more than three years.

Committee Secretary

Any chairman may appoint a secretary with duties usually encompassed by such office.

Size of Committees*

The total membership of any committee shall be limited to 70. In determining the membership of a committee, railroads having no more than 50 Association members may have not more than 2 members on any committee; railroads having 51 to 100 members may have not more than 3 members on any committee; railroads having more than 100 members may have not more than 4 members on any committee.

No college, university or other institution of learning shall have more than 2 members on any committee, and no manufacturer or supply company or other organization shall have more than 1 Associate member on any committee.

Retired Members

Members who have retired from active service under normal retirement procedure, regardless of whether they undertake other employment, may serve on committees a maximum of three years following retirement, but without voting rights. Their presence on the committee roster shall not be counted in the application of the rules affecting the total number of members permitted on committees, the number of associates permitted on a committee, or the rules having bearing upon the number of members on committees permitted from any railroad, supply company, or other organization. Following termination of their service on committees, retired members may continue to attend committee meetings as "visitors" subject to the approval of the committee chairman involved.

Associate Members*

No company will be permitted to have more than one Associate member of any committee, and company representation shall not necessarily be continuing. However, in the event that a railroad member on a committee becomes associated with a manufacturer or supply company after retirement from railroad service on pension, and thus automatically becomes an Associate member, he shall not be deprived of membership on the committee during the period of three years following his retirement from railroad service.

The membership of Associates on a committee shall be limited to 10 percent of the total membership of the committee. Committees with Associates in excess of 10 percent of their total membership are not required to reduce the number of Associates immediately for the purpose of complying with this rule, but no Associates may be

* In applying any of the rules under the headings: Size of Committees and Associate Members see paragraph under heading "Retired Members." and third last paragraph under heading "Member Emeritus."

added as long as the proportion of Associates exceeds 10 percent, except as may be occasioned by the exception provided in the preceding paragraph.

Member Emeritus

This class of committee membership was established in 1953 in order to permit recognition of long-sustained meritorious service of committee members to committees, following their retirement and the termination of their regular membership on committees.

To be eligible for this honor, amember must be in good standing in the Association as a Member, Honorary Member, Associate, or Life Member, and must have:

(a) Retired under normal retirement procedure from active service in the company with which he has been connected.

(b) Served on the committee at least 10 years. (Secretary's office can furnish service record on any retired committee member.)

(c) Resigned from the committee or have been removed from the committee under the rule that retired members can remain on a committee only three years following the date of their retirement.

(d) Rendered outstanding service to the committee over a period of years.

(e) Been proposed by at least five committee members in writing and voted the honor by a two-thirds affirmative letter ballot of all members of the committee, including Associates (the letter ballots to be returnable to the secretary's office within 60 days).

(f) The number of such members permitted on any committee will be limited to five.

Furthermore, his election as Member Emeritus must be affirmed by the Board Committee on Personnel through the secretary's office.

Having been elected as Member Emeritus, the member's name will continue to appear on the roster of the committee, and he will have all the rights and privileges of members except that of voting (i.e., can serve on subcommittees, should he desire, in order that the committee might benefit from his knowledge and experience). Likewise, his name will continue to be shown in the printed roster of the committee appearing in the Bulletins of the Association, and in the Outline of Work Pamphlet, in each case suitably designated as Member Emeritus. However, the names of Members Emeritus will not be designated by an "E" or otherwise in the alphabetical listing, railroad listing, Honorary Member listing, or Life Member listing in the March Bulletin.

Members Emeritus will not be counted in the application of the rules affecting the total number of members permitted on committees, the number of associates permitted on a committee, the rules having bearing upon the number of members on committees permitted from any railroad, supply company, or other organization, or the number of years that a retired member may serve on a committee. Any Emeritus title will terminate with the death of the recipient, or in the event of the termination of his membership in the Association for other reasons.

Nothing in these rules will prevent extending the honor of Member Emeritus to a retired committee member who may have taken up, or who subsequently takes up, other employment following his official retirement.

Tangible evidence of this honor will be given to those so named in the form of a pocket card, similar in form to a railroad pass, signed and sent out by the committee chairmen.

"Guests" and "Visitors"

The previously stated rule under Committee Personnel Reorganized Annually, that "no additions to the personnel of committees will be made during the year following the official closing of committee rosters—October 1, except as provided for under the rules applying to "Guests," does not preclude the attendance at committee meetings of other members of the Association, as "visitors," with the approval of committee chairmen.

If there are vacancies on a committee roster after the official closing of committee rosters on October 1, (i.e., less than 70), or if vacancies occur during the following year, or are definitely in prospect at the end of that year, Association members (including Junior members), with the approval of committee chairmen and the Board Committee on Personnel, can be appointed as "guests" of that committee. As such, they may attend committee meetings and participate in the committee's activities, unofficially, looking to becoming regularly assigned members at the beginning of the next Association year (March).

"Guests" must always be designated as such on the rosters maintained by the committees and the secretary's office, but their names will not appear in published committee or subcommittee reports. Creation of this class of committee affiliation is not intended to increase the size of any committee beyond the 70 maximum set by the Board, but rather to make it possible to add to "short" rosters between official roster changes.

Furthermore, one need not be either a "regular member" or a "guest" of a committee to attend its meetings from time to time. With the approval of the committee chairman, who must be consulted as regards any specific meeting, any AREA member (including Junior members) may sit in on the meeting as a "visitor," listen to all deliberations and participate in discussions.

Service on More Than One Committee

No member of the Association shall serve on more than one committee, except that a member may serve on two committees if one or both of the committees are among the following: Committee 3—Ties; Committee 7—Wood Bridges and Trestles; Committee 17—Wood Preservation; Committee 20—Contract Forms; Committee 24—Cooperative Relations with Universities; Committee 25—Waterways and Harbors; Committee 28—Clearances; Committee 29—Waterproofing; Committee 30—Impact and Bridge Stresses; and the Special Committee on Continuous Welded Rail.

COMMITTEE ORGANIZATION AND PROCEDURE

Organizing the Committees

The new outline of work and personnel of committees shall become effective with the close of the annual meeting in March. However, the pamphlet containing this information is issued not later than January 1 in order that committees may be reorganized immediately after January 1, for the new year's work, if reorganization has not already been effected. Usually this information will be available to the chairmen in tentative form at least 30 days in advance of publication.

It is the duty of the committee chairman to notify new members promptly of their appointment and to notify old members of their reappointment or release. It is also his duty to reorganize the subcommittees without delay. However, in the Association year in which his term as chairman expires, he should call on his successor for advice and assistance in this regard.

Subcommittees

In general, the committees are organized to conduct their work by the appointment of one subcommittee for each subject assignment. If deemed advisable, any subject may be subdivided into several parts and a separate subcommittee assigned to each part. Committees may find it of advantage to create a subcommittee on personnel as well as a subcommittee on new subjects.

Organization Charts

The chairman shall furnish the secretary of the Association two copies of the organization chart (schedule of subcommittee assignments and personnel) of his committee, and shall advise him currently of any subsequent revisions thereof. This chart may be in the form regularly used by committees, but should not be in the form of a blueprint, on which it is difficult to make corrections. White prints are acceptable. These charts should be in the hands of the secretary by February 1, and should be prepared with the greatest care to insure the accuracy of initials and names.

The names of "guest" members on committees, if any, (not "visitors") should appear on the charts, but should be clearly designated as such. These names may be arranged either alphabetically among the members or grouped at the bottom of the chart as desired by the various committees. Names of "visitors" should not appear on or be subsequently added to these charts. Charts should also list separately the names of all collaborators with other AREA committees and with other organizations.

Handbook for Committee Chairmen

For the assistance and guidance of committee chairmen in the conduct of their committee work, the Association has published a small mimeographed "Handbook for Committee Chairmen", which contains the following material:

> Procedures that Can Be Adopted by Committee Chairmen to Stimulate the Most Effective Committee Work.
>
> Procedures Designed to Expedite the Conduct of Committee Meetings, Stimulate Greater Interest in Them, and Produce the Most Effective Results.
>
> Report of a Well Conducted Committee Meeting.

Copies of this handbook are available to committee chairmen from the secretary's office.

Voting in Committees

Voting in committees and subcommittees on all Association matters, except as may be of a social nature, or on ballots for Member Emeritus of the committee, shall be the prerogative of Members only.

COMMITTEE MEETINGS

Location and Number

Most committees find it possible to conduct their work effectively with a maximum of three meetings each year. While these meetings can be held at any time to fit in best with the committees' work, the trend in recent years has been for committees to hold first (organization) meeting each year in January or February in order to get an early start on their new year's work, and not to wait till after the annual convention in March. Subcommittee meetings can likewise be held whenever desired, either in conjunction with or independent of full committee meetings, but are usually held the day prior to general committee meetings at the point of the general meetings.

Committee meetings or subcommittee meetings may be held wherever to the best advantage to committees, but, other things being equal, they should be held at points most convenient to the majority of members in order to hold down traveling time and expense. Meetings should be held where no charge is held for meeting rooms, since the Association has no funds to defray meeting room costs.

Notices and Minutes

The committee chairman shall send copies of all notices of committee meetings to the secretary of the Association as early as possible for publication in the AREA News. Copies of all minutes of meetings must also be filed with the secretary.

COLLABORATION

Between AREA Committees and with AAR Committees

Subjects, the nature of which clearly indicates the possibility of overlapping interest of two or more AREA committees, or the committees of other groups with which the Association has agreed to collaborate, carry an appended clause reading: "collaborating with ...." It is the duty of the chairmen of the subcommittees having an assignment carrying this instruction to take the initiative in effecting such collaboration;—first, by requesting the appointment of representatives of the other interested group or groups, should such be mutually decided or desirable, and second, by submitting copies of AREA reports to them for comment. Regardless of whether the assignment specifically mentions collaboration, committees shall be on the alert to obtain the advice and assistance of other AREA committees or interested groups in dealing with any subject that imposes any questions of possible overlapping interest or responsibility.

A committee undertaking revision of its Manual chapter should request collaboration of any committee that participated in the original development and adoption of the material under revision. The secretary of the Association will provide information concerning such previous collaboration.

With Other Organizations

Many AREA committees appoint representatives to serve as collaborators on committees of the American Standards Association, the American Society for Testing Materials, the American Concrete Institute, or other outside organizations, these representatives acting either directly for the AREA committees or in behalf of the Association of American Railroads which may hold membership in the organizations involved. In all such cases, representation in these other organizations, either initially or otherwise, is handled through the AREA secretary's office. Thus AREA committee nominations for representatives on these outside committees, or for changes in representatives, are made through the secretary's office, which transmits the nominations to the organizations, secures their acceptance, notifies those interested, and makes official record thereof.

Beyond this point the representatives carry on their collaboration independent of the secretary's office, but each AREA committee should keep on its organization chart a record of all of the organizations with which it collaborates, and the names of its collaborators.

WORK OF THE COMMITTEES

Objectives

The objectives of the Association are advanced through the work of the committees in two ways—(1) the development of useful information pertinent to their assignments to be presented to the Association "as information," and (2) the formulation of recommended practices to be submitted for adoption and publication in the Manual.

Planning the Work

In pursuing the work on any assignment, the first step is necessarily one of fact finding, including (a) a study of available literature on the subject, particularly reports of previous investigations, (b) a compilation of current practice, especially recent changes in practice, and (c) resort to original tests or experimentation, after a canvass of all other sources of information indicates that research work is necessary.

Collection of Data

Committees are privileged to obtain data or information in any proper way. If desired, the secretary will issue circulars of inquiry, or questionnaires, prepared by committees, which should be brief and concise. The questions contained in such circulars should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. The circulars should specify to whom answers are to be sent, and should be furnished in duplicate so that a copy can be retained by persons replying.

Research

Requests for appropriations for the conduct of research work should be sent to the secretary of the Association with a supporting statement setting forth: (a) the nature of the information sought; (b) how the railroads are adversely affected by the lack of this information; (c) the estimated cost of the investigation; (d) the estimated time to complete the work; (e) the basis for assuming that the investigation will produce the data desired; and (f) an estimate of the savings to be realized or other advantages to accrue from the successful completion of the investigation. A request for funds to continue or complete an investigation shall include also a statement of the results obtained to date. All requests for research appropriations, with supporting data, must be in the secretary's office by July 1.

Maintaining Manual Up to Date

Each committee shall critically review the material in its chapter of the Manual at such intervals as to insure that it is kept up to date. It shall resubmit all Manual material for revision or reapproval at intervals of not more than 10 years. This rule, however, is not intended to encourage the reapproval of documents only at 10-year intervals. On the contrary, and especially since each document in the newly reprinted Manual carries a reapproval line under its heading, committees are urged to recommend the reapproval of documents each time that revisions (major or minor) are proposed, using some such wording as "Reapprove with the following revisions". If such reapproval is not requested specifically when revisions are recommended, the document will continue to carry its previous adoption or reapproval line.

However, since two or more sheets must be issued in a Supplement every time a document is reapproved without revisions, to correct the document date and the contents page or pages, it is recommended that, in the interest of avoiding unnecessary printing costs, documents which do not require revisions should not be offered for reapproval at intervals of less than 8 or 10 years.

Group Revisions in Specific Years

While it is a healthy situation for committees to be constantly on the alert to improve their respective documents in the Manual, and while some revisions in Manual material will be of a character that will require that they be made at the earliest possible date, many changes will be of an editorial or less-important character and will not demand that they be made immediately.

Accordingly, in the interest of economy, committees should, insofar as possible, group their revisions in any specific document, looking to submitting them as a whole at intervals of two or three years or more, rather than separately year after year—thus avoiding the necessity for reissuing the same Manual pages in successive years, to the greatest extent possible.

NATURE AND PREPARATION OF REPORTS

Form of Report

It is important that committee reports be prepared in accordance with the Style Standards for committee reports, as detailed on following pages in this pamphlet.

Nature of Report

Whether the report on any particular assignment should take the form of "information" or a "recommended practice," depends largely on the nature of the assignment. Some assignments will be fulfilled completely by the presentation of information; others call for information in support of appended recommendations that are submitted for adoption. In still other cases, the primary objective is a comprehensive statement of recommended practices, but the development of these recommended practices may entail investigation or research work, the results of which are of such importance as to warrant their presentation as information prior to the submission of the recommendations. In some cases, it may be advisable to submit as information material in the form of recommended practice with a view to inviting suggestions and criticisms that may serve as the basis for revisions prior to the resubmission of the material for adoption at a later date.

Reports on All Assignments Not Necessary

Committees should pursue their investigations on all assignments but are expected to present progress or final reports for publication only on assignments with respect to which pertinent information has been developed.

When the work has been completed on any assignment, the committee should request the Board Committee on Outline of Work that the assignment be discontinued.

A report should be designated a "final report" only when the committee has completed its study of an assignment and asks that the subject be discontinued, and does not contemplate restudy of the subject in the immediate or foreseeable future; otherwise, the report should be designated a "progress report".

Presentation of Material in Reports

Many progress or final reports, whether based on research or other investigation, best lend themselves to written presentation in orderly sequence or chronological arrangement, ending with any conclusions or recommendations which may have been arrived at. However, in most cases, and especially in the case of long reports, to conserve the time of members who may or may not be interested in the details of the study involved, it is recommended that reports be introduced with a brief highlight summary statement of the background, purpose and extent of the study, as may be desirable, and including a synopsis of any conclusions, recommendations or other results—this latter material to supplement a more detailed presentation elsewhere in the reports.

Reports of information, supplementing previous reports of progress, may include a brief review of material previously presented, but should avoid extended repetition of such material.

Use of Trade Names

Committee reports which are based upon physical research or field tests carried out by or through the research staff of the Engineering Division, AAR, may use trade names or manufacturers' names in referring to products, machines, devices or processes under test. No other committee reports, however, shall contain the trade names of products, machines, devices or processes, nor the names of manufacturers, unless in each instance approval is secured from the Board Committee on Publications prior to the publication of the reports. To seek such approval, a committee must submit five copies of the report in question to the secretary's office, for transmission to the members of the Board Committee, six weeks prior to the scheduled filing date of the report. If time does not permit a ruling upon the request of the committee prior to the publication date of the report in question, the report of the committee must either be altered to eliminate the trade names or terms involved, or be withdrawn, at the discretion of the committee which prepared it.

Nature of Manual Material

The material adopted by the Association for publication in the Manual shall be considered Recommended Practice, but shall not be binding on the members. Recommended Practice, as defined by the Board of Direction (May 20, 1936) is a material, device, plan, specification or practice recommended to the railways for use as required, either exactly as presented or with such modifications as may be necessary or desirable to meet the needs of individual railways, but in either event, with a view to promoting efficiency or economy, or both, in the location, construction, operation or maintenance of railways.

Printing of Manual Material

Material offered for adoption and publication in the Manual, except as noted herein, should be submitted in full, regardless of its publication in previous years, unless the material in question appeared in substantially identical form not more than one year before being submitted for adoption. Such material shall appear in the report of the committee that is published not less than 30 days before the annual meeting at which it is to be presented. Recommended revisions of Manual material, if extensive, shall include only the proposed material, which shall be printed in full in the report of the committee. Manual material recommended for reapproval, or for deletion, shall be presented by title and page reference only. Likewise, plans, specifications or other documents of other organizations recommended for adoption by the AREA shall be presented by title and serial designation only, e.g., current ASTM specifications, designation D 17.

When entirely new material is offered for inclusion in the Manual, the committee sponsoring it should state specifically in its report the exact location the material is to have in the Manual.

Letter Ballot Required of Committee

Any action recommended by a committee with respect to the adoption, revision, reapproval or withdrawal of Manual material must have received prior endorsement by the committee in the form of an affirmative vote of two-thirds of the entire Member membership of the committee, such vote to be taken by letter ballot. Associate and Junior members, and Members Emeritus on a committee are not entitled to vote. Thus, it is imperative that committee members promptly consider and vote on all letter ballots, seeking the advice of other committee members or specially qualified officers on their own roads if in doubt as to whether to vote for or against a proposal.

PUBLICATION OF REPORTS

Dates for Filing Reports

To insure the orderly publication of the reports in accordance with a predetermined schedule, it is necessary that chairmen file complete reports with the secretary of the Association on or before the dates specified in the Outline of Work pamphlet. The manuscript of the report must be furnished in duplicate, preferably double spaced. Piecemeal filing of reports by subcommittee chairmen is permissible only under special arrangement (in writing) with the secretary of the Association.

PRESENTATION OF REPORTS AT ANNUAL MEETINGS

Presentation of Reports

Since both the degree of effectiveness with which a report is received by those assembled in annual convention, and the accuracy with which it can be reported in the Proceedings, depend upon the clarity with which the oral presentation is made to the meeting, it is desirable that committee members write out and read their presentations, and that they speak directly and distinctly into the microphone at the rostrum, raising or lowering the microphone as may be necessary to that end. In the event that written presentations are read, a copy of such presentations should be given to the secretary or to the convention reporter before the speaker leaves the rostrum.

Reports offered as information should be presented by title or by a brief highlight outline of the contents. Material submitted for adoption and publication in the Manual may be presented by reading the title and subtitles, but the presiding officer may, upon request, authorize the reading of specific portions of the material being offered.

Oral Discussions

Comments on or criticisms of any report may be offered from the floor. When necessary to insure accuracy, the speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

Written Discussions

Written discussions of published reports will be transmitted to the chairman of the interested committee who will read or present them by title or in abstract at the convention. Written discussions will be published in the Proceedings as a part of the discussion of the committee reports.

Action on Reports

No formal action is to be taken by the convention on material submitted as information, whether in the form of a progress or final report.

Action on material submitted for adoption and publication in the Manual will be one of the following:

(a) Adoption as a whole as presented.

(b) Affirmative action on the amendment of a part or parts of the material presented, followed by adoption as a whole as amended.

(c) Adoption of a part, complete in itself, and referring the remainder back to the committee for further consideration.

(d) Recommittal with or without instructions.

Note.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the committee considers affected.

The Chair will decline to entertain amendments which in his opinion are primarily a matter of editing.

MISCELLANEOUS

Memoirs

The Association has developed a complete set of rules with respect to memoirs in committee reports or elsewhere in its publications, covering the scope, preparation and presentation of such memoirs. Copy of these rules, as well as the Association service record of any deceased member, can be secured from the secretary's office.

Letter Ballot of Membership

When and as required between annual meetings, recommendations for the adoption, deletion, revision or reapproval of Manual material shall be submitted to letter ballot of the Members of the Association under the following limitations:

(a) That the letter ballot shall be taken only after the Board of Direction has recognized the necessity for such emergency action, and

(b) That the propositions submitted by the committee shall have the approval of a special committee of the Board of Direction appointed by the President for that purpose, both as to the substance of the material offered and also as to the circumstances attending the consideration of the material by the committee.

The Board of Direction, acting under the provisions of paragraphs 6 (a) and 11 of Article VII of the AREA constitution, has the authority to amend, delete or revise Manual material at any time, subject to later confirmation or rejection by the membership, submission to the membership to be effected either by means of a letter ballot immediately following such Board action, or by a motion presented at the annual meeting.

Review by Association of American Railroads

All material adopted for publication in the Manual and all recommendations for the revision or withdrawal of Manual material shall be referred to the vice president, Operations and Maintenance Department, Association of American Railroads, for review, before distribution is made thereof to holders or purchasers of the Manual, or parts thereof.

Publication of Annual Supplement

Revisions of or additions to the Manual authorized by action at each convention will be published annually in the form of loose-leaf sheets which will be made available to all holders of the Manual. These supplemental sheets will be accompanied by instructions for insertion of the new sheets and the withdrawal of sheets that have been superseded, as well as those sheets that have been withdrawn by action of the Association.

Publication of Abstracts by Technical Journals

The following rules will govern the releasing of material for publication in technical journals:

Committee reports to be presented at an annual meeting will not be released for publication until after presentation to the annual meeting. Special articles, contributed by members and others, on which no action by the Association is necessary, will be released for publication in technical journals only after issuance in a Bulletin; provided, application therefor is made in writing and proper credit is given the Association, authors or committees presenting such material.

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